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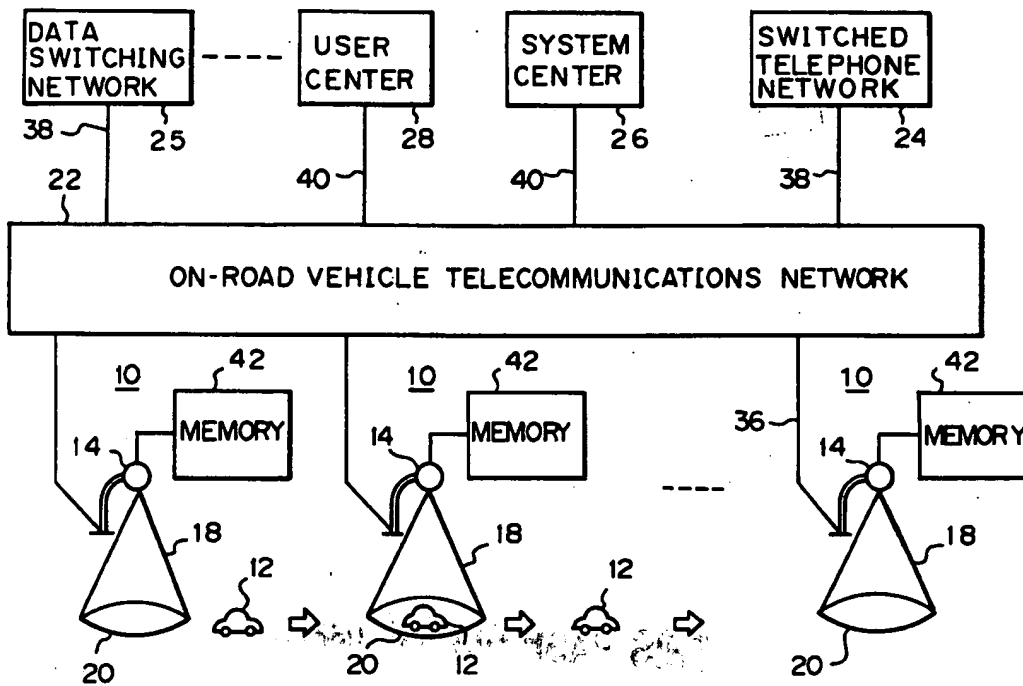
Mobile telecommunications system using distributed miniature zones.

A mobile telecommunications system has multiple base stations (10) each defining a miniature service zone (20) and capable of communicating with mobile stations (16) present in the service zone over a radio link. Geographically associated ones of the base stations (10) are spaced apart from each other by an area in which the mobile stations (16)

are not responsive to electromagnetic waves (18) on the radio links, whereby the base stations (10) are allowed to share the same frequency for the electromagnetic waves (18). The base stations (10) are accommodated in an on-road vehicle telecommunications network (22) which switches communications to the base stations (10).

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Fig. 1



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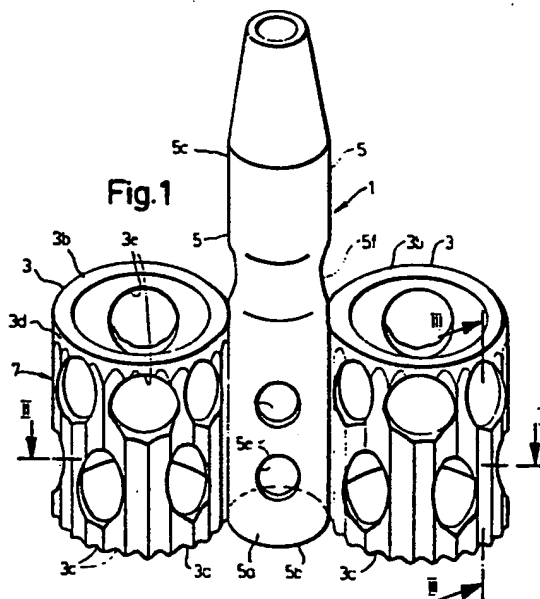
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Implantat zur Befestigung eines künstlichen Zahnersatzes.

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Ein Implantat (1) weist einen zum Verankern in einem Kiefer-Knochen bestimmten Sockel (7) mit mindestens einer im allgemeinen kreiszylindrischen Hülse (3) und einen über den Sockel (7) vorstehenden Pfeiler (5c) zum Halten eines Zahnersatzes auf. Die Aussenfläche der Hülse (3) ist mit über dem Umfang verteilten Rillen (3c) versehen. Diese erstrecken sich von der dem Pfeiler (5c) abgewandten Hülse-Endfläche (3a) nicht ganz bis zur andern Hülse-Endfläche (3b), so dass die Rillen dort durch Endflächen begrenzt werden, die bei einem in einem Kiefer eingesetzten Implantat (1) axiale Druckkräfte übertragen können. Ferner tragen die Rillen (3c) dazu bei, quer zur Pfeilerachse gerichtete, zu übertragende Kräfte gleichmässig über den Hülse-Umfang zu verteilen. Wenn auch bei ihrem pfeilerseitigen Ende vollständig offene Hülsen (3) vorhanden sind, muss zum Ueberdecken der Hülsen (3) nur wenig Knochenmaterial nachwachsen.



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Implantat zur Befestigung eines künstlichen Zahnersatzes

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Die Erfindung betrifft ein Implantat gemäss dem Oberbegriff des Anspruchs 1.

10 Aus der schweizerischen Patentschrift 604 674 ist ein Kieferimplantat bekannt, das einen hülsenförmigen Sockel mit einem im wesentlichen kreiszylindrischen Mantel und einer diesen einend abschiessenden Stirnwand aufweist. Der Sockel hängt bei der Stirnwand mit einem Pfeiler zusammen und ist an seinem andern Ende offen. Im  
15 Mantel und in dem diesen mit der Stirnwand verbindenden Uebergangsteil sind über den Umfang verteilte Bohrungen vorhanden. Der Mantel ist an seiner Aussenfläche ferner noch mit einer schraubenlinienförmig verlaufenden Rippe versehen.

20

Aus der schweizerischen Patentschrift 618 870 sind Kiefer-Implantate mit einem zwei oder drei hülsenförmige, im wesentlichen kreiszylindrische Teile aufweisenden Sockel und einem Pfeiler bekannt, dessen eines  
25 Ende mit dem Sockel verbunden ist und dessen anderes, freies, zum Halten des Zahnersatzes dienendes Ende über die einen Enden der hohlzylindrischen Sockelteile herausragt. Die hohlen, kreiszylindrischen Sockelteile sind an ihren dem freien Pfeiler-Ende abgewandten Enden vollständig offen, während an ihren andern Enden eine Stirnwand vorhanden ist. Die Mäntel und Stirnwände der  
30 hülsenförmigen Sockelteile sind mit Bohrungen versehen,

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deren Durchmesser wesentlich kleiner als der Innendurchmesser der hülsenförmigen Sockelteile ist.

Wenn eines der erwähnten, aus den Schweizerpatentschriften 606 674 und 618 870 vorbekannten Implantate in einem Kiefer eingesetzt werden soll, setzt man dieses so tief in den Kiefer ein, dass auch die Stirnwand des bzw. jedes hohlzylindrischen Sockelteils noch im Knochen versenkt wird und ein wenig unter der ursprünglichen Knochenoberfläche zu liegen kommt. Um ein solches Einsetzen zu ermöglichen, fräst man für den bzw. jeden hohlzylindrischen Sockelteil vorgängig ein Loch in den Knochen, das im tiefsten Teil durch einen zum Mantel des hohlzylindrischen Teils komplementären Ringspalt und in den zum Aufnehmen der Stirnwand dienenden Mündungsteil durch eine volle, kreiszylindrische Bohrung gebildet ist. Nach dem Einsetzen des Implantates wächst dann der Knochen im Laufe der Zeit über der Stirnwand bzw. den Stirnwänden wieder nach, so dass schliesslich nur noch der Pfeiler aus dem Knochen herausragt.

Zum Einsetzen dieser Implantate muss man also im Mündungsbereich der zum Aufnehmen der Sockel dienenden Löcher ziemlich viel Knochen-Material wegnehmen. Es hat sich jedoch gezeigt, dass es manchmal verhältnismässig lange dauert, bis die Stirnwände wieder von Knochen überwachsen sind und bis der Knochen die sich in der Stirnwand befindenden Löcher durchwachsen hat. Dies ist vorallem dann sehr problematisch, wenn ein Implantat in einen Oberkiefer eingesetzt werden soll. Beim Oberkiefer-Knochen ist nämlich die Corticalis, d.h. die Schicht aus verhältnismässig festem Knochenmaterial, im Vergleich zur Corticalis des Unterkiefers nur dünn. Wenn daher im Oberkiefer Löcher der beschriebenen Art gebildet werden müssen, wird das Implantat zunächst nur

von der lockeren Spongiosa gehalten. Ferner ist auch nach dem Nachwachsen des Knochenmaterials im Bereich der Stirnwand nur wenig Knochenmaterial vorhanden. Es ist daher häufig nicht möglich, im Oberkiefer eine ausreichende Verankerung zu erzielen. Zudem weist die Knochenoberfläche, wenn der Knochen die Stirnwände der hohlzylindrischen Sockelteile überwachsen hat, bei diesen meist eine gewisse Senkung auf.

Der Erfindung liegt daher die Aufgabe zugrunde, ein Implantat zu schaffen, bei dem die hülsenförmigen Teile des Sockels bei ihren pfeilerseitigen Enden möglichst schnell überwachsen werden und das auch in einem Knochen, dessen Corticalis verhältnismässig dünn ist, stabil und dauerhaft verankert werden kann.

Diese Aufgabe wird durch ein Implantat der einleitend genannten Art gelöst, das erfindungsgemäss durch die Merkmale des Anspruchs 1 gekennzeichnet ist.

Besonders vorteilhafte Ausgestaltungen des Implantates ergeben sich aus den Ansprüchen 2 bis 4.

Die Erfindung betrifft ferner ein Implantat gemäss dem Oberbegriff des Anspruches 5.

Wenn ein Implantat, das gemäss einer der Schweizerpatentschriften 604 674 und 618 870 ausgebildet ist, in einem Kiefer eingesetzt worden ist, muss es, beispielsweise beim Kauen, beträchtliche Kräfte übertragen. Dabei können sowohl in Längsrichtung des Pfeilers als auch quer dazu gerichtete Kräfte oder Kraftkomponenten auftreten. Dabei können insbesondere infolge der quer zur Pfeiler-Längsrichtung gerichteten Kräfte örtlich sehr grosse Belastungen auftreten, die eine Resorption des Knochenmaterials verursachen und fördern können. Dies

ist vorallem dann der Fall, wenn der Implantat-Sockel nur einen einzigen hülsenförmigen Teil aufweist oder wenn die an einem zwei oder drei hülsenförmige Sockelteile aufweisenden Implantat angreifende Kraft entlang  
5 einer Kraftlinie gerichtet ist, die ungefähr durch die Achsen beider bzw. aller Sockelteile verläuft.

Der Erfindung liegt nun des weitern die Aufgabe zugrunde, ein Implantat zu schaffen, das auch beim Auftreten von quer zur Pfeiler-Längsachse gerichteten  
10 Kräften eine möglichst gleichmässige Kraftverteilung ergibt, wobei das Implantat schon unmittelbar nach dem Einsetzen einigermaßen fest im Knochen sitzen soll.

15 Diese Aufgabe wird durch ein gemäss dem Oberbegriff des Anspruches 5 ausgebildetes Implantat gelöst, das nach der Erfindung durch die Merkmale des Anspruchs 5 gekennzeichnet ist.

20 Zweckmässige Ausgestaltungen des Implantates ergeben sich aus den Ansprüchen 6 bis 10.

Die Erfindung soll nun anhand in der Zeichnung dargestellter Ausführungsbeispiele erläutert werden. In der  
25 Zeichnung zeigen

die Figur 1 eine schaubildliche Darstellung eines Implantates

30 die Figur 2 einen quer zur Längsrichtung des Pfeilers gelegten Schnitt entlang der Linie II-II der Figur 1,

35 die Figur 3 einen Schnitt durch die Mittelachse des Hohlzylinders und die Linie III-III der Figur 1,

- die Figur 4 eine Draufsicht auf die Unterseite  
eines Oberkiefer-Knochens,
- 5 die Figur 5 einen schematischen Schnitt durch den in  
der Figur 4 dargestellten Knochen unmittel-  
telbar nach dem Einsetzen des Implantates,
- 10 die Figur 6 einen der Figur 5 entsprechenden Schnitt,  
aber nachdem der Knochen nachgewachsen  
ist,
- 15 die Figur 7 einen Schnitt durch einen andern Teil  
eines Sockels des in einen Oberkiefer-Kno-  
chen eingesetzten Implantates in grös-  
serem Massstab,
- 20 die Figur 8 ein Diagramm zur Veranschaulichung der  
Kraftübertragung an der Umfangsfläche  
eines zylindrischen Sockelteils, wobei  
zum Vergleich in der linken Figurenhälfte  
die Kraft-Verteilung für einen Sockelteil  
mit einer Rillen aufweisenden Aussen-  
fläche und in der rechten Figurenhälfte  
zum Vergleich die Kraft-Verteilung für  
25 einen Sockelteil mit einer glatt-kreis-  
zylindrischen Aussenfläche eingezeichnet  
ist,
- 30 die Figuren  
9 bis 13 schaubildliche Darstellungen von andern  
Implantat-Varianten,
- 35 die Figur 14 eine Variante eines teils in Ansicht  
teils im Schnitt dargestellten  
Implantates,

- die Figur 15 einen Querschnitt durch das in der Figur 14 dargestellte Implantat,
- 5 die Figur 16 einen Längsschnitt durch einen Kiefer mit einem Implantat, dessen Sockel nur einen hohlzylindrischen Teil aufweist, und
- 10 die Figur 17 ein Diagramm zur Veranschaulichung der quer zur Achse verschiedenartiger zylindrischer Sockelteile gerichteten Auslenkung der Sockelteile.

In den Figuren 1 und 2 ist ein als Ganzes mit 1 bezeichnetes Implantat zum Befestigen eines künstlichen Zahnersatzes an einem Kiefer oder genauer gesagt Kiefer-Knochen dargestellt. Das Implantat 1 besteht aus Metall, beispielsweise Titan oder rostfreiem Stahl, und weist zwei hohle, im allgemeinen kreiszylindrische Teile, nämlich Hülsen 3 auf. Diese sind an ihren beiden Enden vollständig offen, so dass sie also ausschliesslich aus einem an seinen beiden Enden durch radiale Endflächen 3a, 3b begrenzten Hülsenmantel bestehen und weder einen Boden noch eine Deckwand aufweisen. Anders gesagt, weisen die Hülsen eine entlang ihrer Mittel- oder Rotationssymmetrieachse verlaufende kreiszylindrische Durchgangsöffnung auf, die durchgehend den gleichen Querschnitt hat.

Ferner ist ein im allgemeinen rotationssymmetrischer Zapfen 5 vorhanden, dessen Mittel-, Rotationssymmetrie- oder Längsachse parallel zu den Rotationssymmetrie-Achsen der Hülsen 3 verläuft und in der gleichen Ebene liegt wie diese. Im übrigen befindet sich der Zapfen 5 in der Mitte zwischen den beiden Hülsen 3. Der Teil 5a des Zapfens 5 ist dabei starr mit den beiden Hülsen 3

verbunden. Das Implantat besteht vorzugsweise aus einem einstückigen Körper. Der Zapfen könnte aber auch mit den Hülsen 3 verschweisst sein. Bei den Verbindungsstellen des Zapfen-Teils 5a mit den Hülsen 3 durchdringen sich  
5 die zylindrischen Hüllflächen des Zapfen-Teils 5a und der Hülsen 3 ein wenig oder schmiegen sich mindestens aneinander an. Die Endfläche 5b des Zapfen-Teils 5a ist mit der einen Endfläche 3a der Hülsen 3 bündig. Die beiden hohlzylindrischen Hülsen 3 und der Zapfen-Teil 5a  
10 bilden zusammen einen zum Verankern im Kiefer-Knochen bestimmten Sockel 7. Ein Teil des Zapfens 5 ragt über die Endflächen 3b der Hülsen 3 heraus und bildet einen Pfeiler 5c zum Halten eines künstlichen Zahnersatzes.

15 Die Aussenfläche von jeder Hülse 3 ist mit mindestens zehn, vorzugsweise fünfzehn bis dreissig, und beispielsweise ungefähr zwanzig Rillen 3c versehen, die entlang der Mittel- oder Rotationssymmetrieachse der Hülse 3 und des Zapfens 5 verlaufen und, wenn man von der Verbin-  
20 dungsstelle der Hülsen 3 und des Zapfens 5 absieht, gleichmässig über den Hülsen-Umfang verteilt sind. Die Rillen 3c bilden Vertiefungen und ergeben zusammen mit den sich dazwischen befindenden Stegen, Rippen oder Erhöhungen eine wellenförmige Profilierung. In den  
25 rechtwinklig zu der Hülsen-Achsen gelegten Schnitten sind die Rillen 3c, die sich dazwischen befindenden Erhöhungen und die Uebergänge zwischen den Rillen und Erhöhungen stetig verrundet. Die Rillen 3c münden in die Endfläche 3a der Hülsen 3, erstrecken sich dagegen nicht  
30 ganz bis zur andern Endfläche 3b. Wie man aus der Figur 3 ersehen kann, werden die Rillen 3c kurz vor der Endfläche 3b durch nach aussen in die kreiszyllindrische Hüllfläche laufende, gebogene Endflächen 3h begrenzt. Bei dem sich in der Figur 1 oben befindenden Hülsenrand

hat also die Aussenfläche des Hülsenmantels zwischen den Enden der Rillen 3c und der Endfläche 3b einen glatt-zylindrischen, rillenlosen Streifen 3d, dessen Aussen-durchmesser gleich dem Durchmesser D der kreiszylin-  
5 drischen Hüllfläche des die Rillen 3c aufweisenden Abschnittes der Hülsen 3 ist.

Im übrigen sind in den Hülsen 3 eine Anzahl über deren Mäntel verteilter Durchgangslöcher 3e vorhanden. Diese  
10 sind durch Bohrungen gebildet, deren Durchmesser grösser als die Breite der Rillen 3c ist und die die Rillen 3c kreuzen und teilweise unterbrechen. Die Löcher 3e können beispielsweise derart auf zwei entlang der Zylinderachsen gegeneinander versetzten Kreisen verteilt sein,  
15 dass sich die auf einem Kreis angeordneten Löcher in der Mitte zwischen zwei auf dem anderen Kreis angeordneten Löchern befinden. Dabei sind auf jedem Kreis mindestens drei Löcher 3e, und beispielsweise auf dem einen Kreis drei und auf dem anderen vier Löcher angeordnet. Die  
20 beiden stirnseitigen Randabschnitte jeder Hülse 3 hängen dann bei verschiedenen Umfangstellen durch zwischen den Löchern 3e hindurch verlaufende Stege zusammen. Anders gesagt, weist jede Hülse 3 bei mehreren entlang ihrem Umfang gegeneinander versetzten Stellen über die ganze  
25 Hülsenlänge zusammenhängende Mantelabschnitte auf. Von diesen verlaufen die die Hülsen 3 mit dem Zapfen 5 verbindenden Mantelabschnitte geradlinig und parallel zu den Hülsenachsen, während die restlichen dieser Mantelabschnitte ungefähr Zickzack- oder Z-förmig zwischen den  
30 Löchern 3e hindurch verlaufen.

Die maximalen Aussendurchmesser D und die Längen oder Höhen der Hülsen 3 sind ungefähr gleich gross und betragen zweckmässigerweise mindestens etwa 4 mm und beispielsweise 5 bis 6 mm. Die maximalen Wandstärken w der  
35

Hülsenmäntel und damit die radial gemessenen Breiten der Endflächen 3b betragen mindestens 7 % und höchstens 15 %, beispielsweise etwa 10 % des maximalen Aussendurchmessers D der Hülsenmäntel. Die maximalen Wandstärken w der Hülsen 3 betragen beispielsweise mindestens etwa 0,35 mm und höchstens etwa 0,9 mm und beispielsweise 0,5 bis 0,6 mm. Die Längen der Rillen 3c sind 0,1 bis 1 mm kürzer als die Längen oder Höhen der Hülsen 3. Die Tiefe t der Rillen 3c beträgt mindestens 20 %, zweckmässigerweise mindestens 30 und höchstens 70 % und vorzugsweise etwa 35 bis 60 % der Wandstärke w. Die Tiefe t kann beispielsweise etwa 0,1 bis 0,3 mm betragen. Der Abstand benachbarter Rillen beträgt zweckmässigerweise mindestens 0,4 mm und beispielsweise 0,6 bis 0,8 mm und die Rillenbreite beträgt bei der halben Rillentiefe zweckmässigerweise mindestens 0,2 und beispielsweise 0,3 bis 0,4 mm. Im weitem sind die Formen und Abmessungen der Rillen beispielsweise derart festgelegt, dass die durch die Bildung der Rillen 3c verursachte Vergrösserung der Hülsenmantel-Aussenfläche bezüglich einer gelochten, aber rillenlosen Schmieg-Zylinderfläche mindestens 50 %, vorzugsweise mindestens 80 % und beispielsweise ungefähr 80 bis 100 % beträgt.

25

Der Zapfen-Teil 5a ist mit einer kreiszylindrischen Längsöffnung 5d versehen, die sich von seiner Endfläche 5b bis in die Höhe der Hülsen-Endflächen 3b erstreckt. Der Zapfen-Teil 5a bildet also ebenfalls eine Hülse, die aber nur an ihrem dem Pfeiler 5c abgewandten Ende offen ist. Die Wand des Zapfen-Teils 5a ist im übrigen ebenfalls von Löchern 5e, d.h. Bohrungen durchbrochen. Der Aussendurchmesser des des Zapfen-Teils 5a ist auch der grösste Durchmesser des ganzen Zapfens 5 und kleiner als der Hülsen-Durchmesser D und kann beispielsweise 2,5 bis 3,5 mm betragen.

Der Pfeiler 5c kann in der Nähe der Hülsen-Endfläche 3b mit einer Einschnürung 5f versehen sein, deren Uebergänge mit den anschliessenden Abschnitten des Zapfens 5 stetig verrundet sind. Der freie Endabschnitt des Pfeilers 5c verjüngt sich zu seinem Ende hin konisch.

In den Figuren 4, 5 und 6 ist ein Teil eines Oberkiefer-Knochens 9 dargestellt. Beim Oberkiefer-Knochen bildet die verhältnismässig kompakte und stabile Corticalis 9a mindestens in gewissen Bereichen nur eine ziemlich dünne Randzone. Das Innere des Knochens besteht dann aus der relativ lockeren Spongiosa 9b, wobei die beiden Knochenmaterialien in einer Uebergangszone mehr oder weniger stetig ineinander übergehen. In den Figuren 5 und 6 wie übrigens auch in der Figur 7, ist die Corticalis durch eine feine Punktierung und die Spongiosa durch eine grobe Körnung dargestellt.

Zum Einsetzen eines Implantates 1 in einen Oberkiefer werden zuerst die nicht dargestellten, weichen Gewebeteile soweit als nötig entfernt und der Oberkiefer-Knochen 9 freigelegt. Danach wird zuerst eine volle Bohrung 9c in den Knochen 9 gebohrt, die nachher zum Aufnehmen des Zapfen-Teils 5a dient und einen dem letzteren entsprechenden Aussendurchmesser aufweist. In diese Bohrung 9c wird eine Lehre eingesetzt. Anschliessend werden mit Hilfe dieser Lehre zwei nachher zum Aufnehmen der Hülsen 3 dienenden Ringnuten 9d in den Knochen 9 gebohrt oder gefräst. Derartige Ringnuten 9d werden in der Chirurgie häufig als Trephine- oder Trepan-Bohrungen bezeichnet. Der Innendurchmesser der Ringnuten 9d ist ungefähr gleich dem Innendurchmesser der Hülsen 3. Der Aussendurchmesser der Ringnuten 9d ist ungefähr gleich dem Hülsen-Aussendurchmesser D und vorzugsweise etwa um die Rillentiefe t kleiner als dieser, so dass die Hülse 3 zum Einsetzen eingepresst werden müssen und das Knochen-

material schon beim Einsetzen des Implantates in die Rillen 3c eindringt. Die Tiefe der Ringnuten 9d wird so bemessen, dass die Hülsen 3 vollständig im Knochen 9 versenkt werden können, dass aber die sich in der Nähe  
5 der Endflächen 3b befindenden Abschnitte der Hülsen und Rillen 3c mindestens teilweise noch in der Corticalis 9a liegen, wie es besonders deutlich aus der Figur 5 ersichtlich ist.

10 Wenn das Implantat in den Knochen 9 eingesetzt ist, sind also noch Knochenzapfen 9e vorhanden, die die Innenräume der Hülse 3 durchdringen und ausfüllen und vorzugsweise noch etwas aus diesen herausragen. Das Implantat sitzt schon unmittelbar nach dem Einpressen in den Knochen  
15 verhältnismässig starr in diesem fest, wodurch das Anwachsen von Knochenmaterial an das Implantat gefördert wird. Nach dem Einsetzen des Implantates in die im Knochen angebrachten Löcher schliesst das Implantat die inneren und grössten Teile dieser Löcher bei den  
20 pfeilerseitigen Rändern der Hülsen 3 annähernd dicht ab. Zu diesem annähernd dichten Abschluss der grössten Teile der Löcher trägt insbesondere auch die Tatsache bei, dass sich die Rillen 3c nicht ganz bis zu den pfeilerseitigen Enden der Hülsen 3 erstrecken, so dass die  
25 Hülsen bei diesen Enden nicht nur innen, sondern auch aussen durch eine glatte, kreiszylindrische Fläche begrenzt sind. Dieser praktisch dichte Abschluss der inneren Teile der im Knochen vorhandenen Löcher wirkt einem Eindringen von Mikroorganismen in diese Löcher und  
30 damit der Entstehung einer Infektion entgegen.

Nach dem Einsetzen des Implantates 1 wächst das Knochenmaterial durch die Löcher 3e, 5e hindurch sowie auch über die ringförmigen Hülsen-Endflächen 3b. Ferner  
35 wächst das Knochenmaterial auch in die Rillen 3c hinein, soweit es nicht bereits beim Einsetzen des Implantates

in diese hineingelangt ist. Wenn sich der Knochen regeneriert hat und nachgewachsen ist, ergibt sich dann der in den Figuren 6 und 7 dargestellte Zustand, in dem der Sockel 7 vollständig von Knochenmaterial umschlossen und durchdrungen ist. Zum Ueberdecken der Hülsen 3 muss  
5 nur verhältnismässig wenig Knochenmaterial nachwachsen, nämlich nur gerade soviel, wie zum Ueberdecken der ringförmigen Endflächen 3b der Hülsenmäntel notwendig ist. Der Implantat-Sockel 7 ist daher nach dem Einsetzen des  
10 Implantates in verhältnismässig kurzer Zeit, abgesehen von dem mit dem Pfeiler 5c zusammenhängenden Zapfen-Teil 5a, vollständig von Knochenmaterial überdeckt. Wenn der Knochen die Hülse 3 überwachsen hat, weist er auch in deren Bereichen wieder ungefähr die ursprüngliche Höhe  
15 auf. Die Knochenaussenfläche verläuft dann, ohne dass bei den Hülsen eine Senke vorhanden ist, glatt bis zum Zapfen 5. Die Tatsache, dass die Hülsen 3 an beiden Enden vollständig offen sind und dass auch noch ihre Mäntel mit Löchern versehen sind, ermöglicht eine gute  
20 Blutversorgung der in den Hohlräumen der Hülsen vorhandenen Knochenteile. Dies wiederum trägt dazu bei, dass diese Knochenteile immer wieder regeneriert und auch bei grossen Belastungen lebend erhalten werden. Im übrigen bilden sich dann auch noch in den Figuren 4 bis 7 nicht  
25 dargestellte weiche Gewebeteile, die den Knochen umschliessen und in die Einschnürung 5d hineinwachsen. Am Pfeiler 5c kann dann ein künstlicher Zahnersatz 11, beispielsweise eine Brücke befestigt werden.

30 Wenn der Knochen 9 auf diese Weise gewissermassen mit dem Sockel 7 verwachsen ist, befinden sich also die bogenförmigen Endflächen 3h der Rillen 3c, wie in der Figur 7 dargestellt, in der Corticalis. Die Endflächen der Rillen 3c tragen daher dazu bei, in der Pfeiler-  
35 Längsrichtung vom Pfeiler 5c zum Sockel 7 gerichtete Druckkräfte auf den Knochen zu übertragen, und zwar auf

dessen Corticalis, die, wie erwähnt, kompakter und stabiler ist als die Spongiosa.

Die Rillen 3c sind jedoch vorallem auch sehr wichtig für  
5 die Uebertragung von quer zur Längsachse des Pfeilers 5c  
gerichteten Kräften. Es soll nun anhand der Figur 8 er-  
läutert werden, wie eine quer zur Rotationssymmetrie-  
achse des Pfeilers 5c, gerichtete Kraft P vom Knochen 9  
auf eine Hülse 3 übertragen wird, wenn der Knochen in  
10 der vorgängig beschriebenen Weise in die Rillen 3c ein-  
gewachsen ist. Die Kraft P sei parallel zu einer Geraden  
gerichtet, die die Rotationssymmetrieachse der Hülse 3  
rechtwinklig schneidet. In der linken Hälfte der Figur 6  
ist schematisch der Umriss einer Hülse 3 dargestellt.  
15 Die Flanken dieser Rippen bilden nun auch an derjenigen  
Umfangsstelle, die am weitesten von der Geraden 15 ent-  
fernt ist, Flächen, die nicht parallel zur Richtung der  
Kraft P verlaufen, sondern mit dieser Richtung einen  
Winkel zwischen etwa  $45^{\circ}$  und  $135^{\circ}$  bilden. Dies gewähr-  
20 leistet, dass auch bei den am weitesten von der Geraden  
15 entfernten Umfangsstellen noch Kräfte vom Knochen auf  
die Hülse 3 und umgekehrt übertragen werden. Bei der  
Uebertragung der Kraft P wird die letztere daher in  
Teilkräfte aufgeteilt, deren Grösse und örtliche Ver-  
25 teilung qualitativ durch Pfeile 17 angedeutet ist. Die  
zu übertragende Kraft P wird also relativ gleichmässig  
auf einen grossen Teil des Umfangs der Hülse 3 verteilt.  
Ferner tragen natürlich auch die Begrenzungsflächen der  
Löcher 3e, 5e zur Kraftübertragung bei. Daraus resul-  
30 tiert eine relativ gleichmässige örtliche Verteilung der  
Kräfte und Beanspruchungen des Knochenmaterials.

Wenn die Aussenfläche des Hülsenmantels dagegen eine  
glatte Zylinderfläche wäre, ergäbe sich die qualitativ  
35 in der rechten Hälfte der Figur 8 durch die Pfeile 19

dargestellten Teil-Kräfte. Die relativ weit von der Geraden 15 entfernten Umfangsbereiche der Hülse wären dann für die Uebertragung der Kraft P praktisch unwirksam.

5

Wenn man beim Bohren der Löcher in den Knochen den Aus-  
sendurchmesser der Ringnuten 9d, wie erwähnt, ungefähr  
um eine Rillentiefe  $t$  kleiner macht als den Durchmes-  
ser  $D$  der Hüllflächen der Hülse 3, so tragen die Ril-  
10 len 3c bereits unmittelbar nach dem Einsetzen des Im-  
plantates dazu bei, Kräfte zwischen dem Implantat und  
dem Knochen zu übertragen. Um den Einfluss der Rillen  
auf die Übertragung von quer zur Achse einer Hülse 3  
gerichteten Kräfte quantitativ erfassen zu können,  
15 wurden zum Vergleich ein Zylinder mit einer glatten und  
ein Zylinder mit einer Rillen aufweisenden Aussenfläche  
in einen künstlichen Knochen aus Kunststoff eingepresst,  
die Zylinder mit einer quer zu ihrer Achse gerichteten  
Kraft beaufschlagt und die seitliche Auslenkung der  
20 Zylinder gemessen. Beim benutzten künstlichen Knochen  
handelte es sich um einen Knochen der ähnliche Festig-  
keitseigenschaften hat wie die natürliche Spongiosa. Die  
Messbedingungen entsprechen daher ungefähr den Verhält-  
nissen, wie sie unmittelbar nach der Operation vorhanden  
25 sind, wenn ein Implantat in den Knochen eingepresst  
wurde, aber noch nicht festgewachsen ist. Die Messer-  
gebnisse sind in dem in der Figur 17 dargestellten Dia-  
gramm wiedergegeben, in dem auf der Abszisse die quer  
zur Zylinderachse auf die Zylinder ausgeübte Kraft  $P$  und  
30 auf der Ordinate die quer zur Zylinderachse gerichtete  
Zylinderauslenkung  $y$ , d.h. die Verschiebung des  
Zylinders aus der Ruhelage, aufgetragen ist. Die obere  
gestrichelte Kurve des Diagramms zeigt die Auslenkung  
eines Zylinders mit einer glatten, rillenlosen Mantel-  
35 fläche und die untere, mit einer vollen Linie

gezeichnete Kurve zeigt die Auslenkung eines Zylinders, dessen Mantelfläche mit ähnlichen Rillen versehen ist wie die Hülsen des Implantates. Wie aus dem Diagramm er-  
sehen werden kann, wird der Rillen aufweisende Zylinder  
5 im ganzen Bereich nur ungefähr halb so viel ausgelenkt wie der Zylinder mit der glatten Aussenfläche. Dies belegt, dass die Stabilität der Implantat-Verankerung durch die Rillen beträchtlich verbessert wird.

10 Die nach der Regeneration des Kochens bei beiden Stirnseiten der Hülsen 3 vorhandenen, aus Knochenmaterial bestehenden Verbindungen zwischen hülseninneren und hülsenäusseren Knochenteilen tragen ebenfalls wesentlich zur Verankerung des Implantates und insbesondere zur  
15 Übertragung von quer zu den Hülsenachsen gerichteten Kräften zwischen dem Implantat und dem Knochen bei. Durch die zwischen die Rillen 3c hineinragenden Knochenteile und, wenn der Knochen die Löcher 3e und 5e durchwachsen und die Endfläche 3b überwachsen hat, auch  
20 durch die bei diesen Löchern und den Hülsenenden vorhandenen Knochenverbindungen werden bei der Kraftübertragung zwischen dem Implantat und dem Knochen insbesondere auch die bei den Grenzflächen zwischen dem Implantat und dem Knochen auftretenden, tangentialen  
25 Schubspannungen reduziert. Dies trägt dazu bei, bei den Grenzflächen einen Abbau von Knochenmaterial zu vermeiden.

Das in der Figur 9 dargestellte Implantat 21 weist vier  
30 hohle, im allgemeinen kreiszylindrische, beidseitig offene Hülsen 23 auf, die ähnlich ausgebildet sind wie die Hülsen 3 und insbesondere auch den Rillen 3c entsprechende Rillen 23c sowie Durchgangslöcher 23e aufweisen. Zwischen den beiden mittleren Hülsen 23 befindet  
35 sich ein längerer Zapfen 25, dessen einer Teil 25a starr mit den beiden benachbarten Hülsen 23 verbunden ist und

mit diesen zusammen den in einem Kiefer verankerbaren Sockel 27 bildet. Die Achsen der Hülsen und des Zapfens 25 liegen dabei alle in der gleichen Ebene. Der Zapfen-Teil 25a hat ungefähr den gleichen Durchmesser wie die  
5 Hülsen 23 und ist ebenfalls als Hohlzylinder ausgebildet, der an seinem mit dem einen Hülsenende bündigen Ende offen ist. Ferner ist der Mantel des Zapfen- Teils 25a mit Durchgangslöchern 25e versehen. Der über die Hülsen 23 herausragende Endabschnitt des Zapfens 25  
10 bildet einen Pfeiler 25c zum Halten eines Zahnersatzes.

Das in der Figur 10 dargestellte Implantat 31 weist zwei hohle, im allgemeinen kreiszylindrische, beidseitig offene Hülsen 33 auf, die mit den Rillen 3c entsprechenden  
15 Rillen 33c versehen sind. Die Mäntel der Hülsen 33 sind mit Löchern 33e in der Form von rechtwinklig zu den Mittelachsen der Hülsen verlaufenden Schlitzern versehen. Ferner ist ein Zapfen 35 vorhanden, der beispielsweise den gleichen Aussendurchmesser hat wie die Hülsen 33 und  
20 dessen Teil 35a durch je einen Steg 39 starr mit den Hülsen 33 verbunden ist, so dass die Achsen der Hülsen 33 und des Zapfens 35 parallel zueinander verlaufen und in der gleichen Ebene liegen. Die rechtwinklige zu dieser Ebene gemessene Breite der Stege 39 ist wesentlich  
25 kleiner als der Aussendurchmesser der Hülsen 33 und des Zapfens 35 und beträgt höchstens 50 % und beispielsweise ungefähr 30 bis 40 % dieser Aussendurchmesser. Die Hülsen 33, der Zapfen-Teil 35a und die Stege 39 bilden zusammen den zum Verankern in einem Kiefer-Knochen bestimmten Sockel 37. Der Zapfen-Teil 35a ist hohl und  
30 sein Mantel ist von Durchgangslöchern 35e durchbrochen, die durch quer zur Stab-Längsachse verlaufende Schlitzze gebildet sind. Die Stege 39 sind von je mindestens einem runden Loch 39e durchbrochen. Der über den Sockel 37

vorstehende Teil des Zapfens 35 bildet einen Pfeiler 35c zum Halten eines Zahnersatzes.

Das in der Figur 11 dargestellte Implantat 41 weist zwei  
5 hohle, im allgemeinen kreiszylindrische, beidenends  
vollständig offene Hülsen 43 mit Endflächen 43a, 43b,  
Rillen 43c und runden Löchern 43e und einen Zapfen 45  
mit einem hohlen Teil 45a auf, der mit runden Löchern  
45e versehen und durch zwei ein rundes Loch 49e auf-  
10 weisende Stege 49 mit den Hülsen 43 verbunden ist. Der  
Sockel 47 des Implantates 41 besteht also gleich wie der  
Sockel 37 des Implantates 31 aus zwei Hülsen, einem  
Zapfen-Teil und zwei Stegen, unterscheidet sich aber vom  
Sockel 37 insbesondere dadurch, dass die Höhe der Stege  
15 49 kleiner ist als die Höhe oder Länge der Hülse 43. Die  
Stege 49 erstrecken sich nämlich von den Endflächen 43b  
der Hülsen 43 aus nur bis ungefähr zur halben Höhe der  
Hülsen. Die Endfläche 45b des Zapfen-Teils 45a ist  
bündig mit den sich ungefähr in halber Hülsenhöhe  
20 befindenden Stegrändern. Der über den Sockel 47 her-  
ausragende Teil des Zapfens 45 bildet wiederum einen  
Pfeiler 45c zum Halten eines Zahnersatzes.

Das in der Figur 12 dargestellte Implantat 51 weist zwei  
25 hohle, im allgemeinen kreiszylindrische, beidenends  
offene Hülsen 53 auf. Ihre Mäntel sind analog wie die-  
jenigen der Hülsen 3 mit Rillen 53c und runden Löchern  
53e versehen. Ferner sind zwei Zapfen 55 vorhanden,  
deren Teile 55a zusammen mit den beiden Hülsen 53 den  
30 Sockel 57 des Implantates bilden. Die Rotationssym-  
metrieachsen der Hülsen 53 und Zapfen 55 verlaufen  
parallel zueinander und liegen alle in der gleichen  
Ebene und die beiden Hülsen 53 sind zwischen den beiden  
Zapfen 55 angeordnet wobei die Hülsen und Zapfen  
35 paarweise starr miteinander verbunden sind. Die

Zapfen-Teile 55a sind hohlzylindrisch und mit Rillen 55c versehen, die gleich ausgebildet sind und sich bis in die gleichen Höhen erstrecken wie die Rillen 53c. Im übrigen sind die Mäntel der hohlen Zapfen-Teile 55 mit runden Durchgangslöchern 55e versehen. Die über den Sockel 57 herausragenden Zapfen- Teile bilden zwei zum Verankern eines Zahnersatzes dienende Pfeiler 55d.

Das in der Figur 13 dargestellte Implantat 61 weist zwei Zapfen 65 auf, deren sich in der Figur 13 unten befindende Teile als hohle, im allgemeinen kreiszyklische, gegen unten offene Hülsen 63 ausgebildet sind. Diese Hülsen 63 bilden zusammen mit einem sie starr verbindenden Steg 69 den in einem Kiefer-Knochen verankerbaren Sockel 67. Die sich in der Figur 13 oberhalb des Steges 69 befindenden Zapfen-Teile bilden Pfeiler 65c zum Halten eines Zahnersatzes. Die Rotationssymmetrieachsen der beiden Zapfen 65 sind zueinander parallel und liegen in der gleichen Ebene, wogegen der Steg 69 bezüglich dieser Ebene ein wenig gebogen ist. Bei Betrachtung in einer zu den Zapfenachsen parallelen Blickrichtung ist also das ganze Implantat etwas gebogen. Die Aussenfläche jeder Hülse ist mit über den Umfang verteilten Rillen 63c versehen. Diese erstrecken sich von der Hülsen-Endfläche 63a bis ungefähr in die Höhe des weiter von dieser entfernten Randes des Steges 69 und werden dort durch eine gebogene, nach aussen laufende Endfläche begrenzt. Im übrigen weist die Hülse runde Durchgangslöcher 63e und der Steg runde Durchgangslöcher 69e auf.

Bei den in den Figuren 9, 10, 11, 12 und 13 dargestellten Implantaten sind die beiden äussersten Hülsen verhältnismässig weit voneinander entfernt. Dies erlaubt, die Durchmesser der Hülsen etwas kleiner

festzulegen als beim Implantat 1, ohne dass dadurch die Festigkeit der Verankerung beeinträchtigt wird. Beispielsweise kann man bei dem in der Figur 10 dargestellten Implantat 31, wie bereits erwähnt, den Durchmesser der Hülsen 33 etwa gleich gross wie den Durchmesser des Zapfens 35 machen. Diese Durchmesser können dann ohne weiteres kleiner als 4 mm sein und vorzugsweise mindestens 2 mm und beispielsweise ungefähr 2,5 bis 3,5 mm betragen.

10

Für die in den Figuren 10, 11 und 13 dargestellten Implantate, bei denen der Sockel auch noch mindestens einen Steg aufweist, kann man die zum Aufnehmen der Stege bestimmten Rinnen im Knochen beispielsweise dadurch bilden, dass man eine Reihe einander teilweise überlappender Bohrungen in den Knochen bohrt.

Das in den Figuren 14 und 15 dargestellte Implantat 71 besteht aus einem abgestuften, im allgemeinen rotations-symmetrischen, einstückigen Zapfen. Der sich in der Figur 14 unten befindende, dickere Teil des Zapfens ist durch eine im allgemeinen hohlzylindrische Hülse 73 gebildet und dient als zum Verankern in einem Kiefer bestimmter Sockel. Der restliche Zapfen-Teil bildet den zum Halten des Zahnersatzes dienende Pfeiler 75. Beim Uebergang zwischen der Hülse 73 und dem Pfeiler 75 ist eine vorzugsweise verrundete Schulter vorhanden. Die Hülse 73 ist an ihrem dem Pfeiler 75 abgewandten Ende offen, an ihrem pfeilerseitigen Ende jedoch durch den Pfeiler 75 und den schulterförmigen Uebergang geschlossen.

Die Aussenfläche des Hülsenmantels ist mit über den Umfang verteilten Rillen 73c versehen. Diese verlaufen

35

parallel zur Rotationssymmetrieachse des Implantates 71 und erstrecken sich von der radialen, ringförmigen Endfläche 73a der Hülse 73 nicht ganz bis zur erwähnten Schulter, wo sie durch gebogene, nach aussen laufende Endflächen begrenzt werden. Im übrigen können die Rillen 73c ähnlich ausgebildet und bemessen sein, wie es für die Rillen 3c erläutert wurde.

Der Mantel der Hülse 73 ist ferner mit Durchgangslöchern 73e, nämlich Bohrungen versehen, wobei auch noch im Bereich der erwähnten Schulter Löcher vorhanden sind. Der Pfeiler 75 ist mit einem als Gewindebohrung ausgebildeten Sackloch versehen.

Wie im Hinblick auf das Implantat 1 anhand der Figuren 5, 6, 7, 8 und 17 erörtert wurde, ergeben die Rillen und Löcher in den Hülsen des Implantat-Sockels eine beträchtliche Verbesserung der Kraftübertragung zwischen Implantat und Knochen. Das Entsprechende gilt natürlich auch für alle anderen in der Zeichnung dargestellten Ausführungsvarianten.

Es sei hierbei darauf hingewiesen, dass die Rillen insbesondere bei dem in den Figuren 14 und 15 dargestellten Implantat 71, dessen Sockel ja ausschliesslich durch eine einzige, im allgemeinen zylindrische, am pfeilerseitigen Ende abgeschlossene Hülse gebildet ist, von grossem Nutzen für die Verankerung sind und dass im wesentlichen alle anhand der Figuren 5,6,7 sowie insbesondere 8 und 17 erörterten Wirkungen der Rillen 3c in analoger Weise auch durch die Rillen 73c des Implantates 71 bewirkt werden. Die Rillen und Löcher des Hülsen-Mantels gewährleisten insbesondere auch die Torsionsfestigkeit der Verankerung, d.h. die Sicherung des Implantats gegen Drehungen um seine Längsachse. Wenn

- der Aussendurchmesser des zum Aufnehmen des Implantates 71 in den Knochen gebohrten Loches, dessen knocheninnerer Teil vorzugsweise durch einen Ringspalt gebildet ist, analog wie es im Hinblick auf das Implantat 1 beschrieben wurde, etwas kleiner gemacht wird als der maximale Hülsen-Aussendurchmesser, ergeben die Rillen schon unmittelbar nach dem Einsetzen des Implantates eine Sicherung gegen Verdrehungen von diesen.
- 10 Während die Implantate 1, 21, 31, 51 und 61 vorallem zur Befestigung von Zahnbrücken geeignet sind, kann das nur eine einzige Hülse aufweisende Implantat 71 auch zum Befestigen einzelner, künstlicher Zähne eingesetzt werden. Da die Ausbildung der Kieferknochen und Zähne
- 15 individuell stark variieren, können Implantate mit unterschiedlichen Sockel-Abmessungen, insbesondere unterschiedliche Hülsen-Längen bereit gestellt werden, so dass ein Zahnarzt oder Chirurg jeweils ein Implantat auswählen kann, das für den individuellen Fall möglichst
- 20 günstig ist.

In der Figur 16 ist die Anordnung eines Implantates 71 dargestellt. Das Implantat 71 ist in einen Knochen 99, beispielsweise einen Unterkiefer eingesetzt und sein

25 Sockel ragt ungefähr gleich tief in diesen hinein, wie die Wurzeln der sich neben ihm befindenden, natürlichen Zähne. Am Pfeiler des Implantates 71 ist ein vereinfacht dargestellter Zahnersatz, d.h. künstlicher Zahn 101 befestigt. In der Figur 16 ist auch noch das den Knochen 99 überziehende Bindegewebe dargestellt, das den

30 unteren Teil des Pfeilers des Implantates umschliesst. Das Implantat 71 ermöglicht, zwischen natürlichen Zähnen, zwischen denen nur ein einziger natürlicher Zahn fehlt und nur wenig Platz verfügbar ist, einen einzelnen

35 künstlichen Zahn dauerhaft am Kiefer zu befestigen, ohne

dass dieser künstliche Zahn in irgend einer Weise zusätzlich von einem natürlichen Zahn gehalten werden muss.

- 5 Die verschiedenen beschriebenen Implantate werden zweckmässigerweise aus einem kompakten, d.h. im wesentlichen porenfreien, vorzugsweise aus Titan bestehenden Grundkörper gebildet, auf den durch ein Plasmabeschichtungsverfahren eine dünne, körnige Titanschicht mit einer  
10 beispielsweise in der Grösse von 0,01 bis 0,02 mm liegenden Rauheit aufgebracht wird. Dadurch wird die Haftfestigkeit am Knochen zusätzlich verbessert.

Die Zahnimplantate können noch in verschiedener Hinsicht  
15 modifiziert werden.

Beispielsweise könnte man bei den Implantaten 1, 21, 31, 41 und 51 die Hülsen und Pfeiler derart versetzen, dass ihre Achsen zwar noch zueinander parallel sind, aber  
20 nicht mehr in der gleichen Ebene, sondern in einer gebogenen Fläche liegen.

Ferner könnte der Pfeiler der Implantate bei seiner Verbindung mit dem Sockel eine verrundete Einschnürung  
25 aufweisen.

Des weitern könnte man bei den Implantaten 1, 21, 31 und 41 auch noch die zum Sockel gehörenden Zapfen-Teile 5a, 25a, 35a, 45a mit analog zu den Rillen 3c ausgebildeten  
30 Rillen versehen. Ferner könnten bei den Implantaten 31, 41, 61 auch die zum Sockel gehörenden Stege mit parallel zu den Pfeilerachsen verlaufenden und analog zu den Rillen 3c ausgebildeten Rillen versehen werden.

Ferner könnten die Aussenflächen der Längsrillen aufweisenden Hülsen zusätzlich noch mit Rillen versehen werden, die ringförmig oder schraubenlinienförmig um die Hülsen herum verlaufen. Diese zusätzlichen Rillen würden  
5 dann die vorhandenen Längsrillen kreuzen und die zwischen diesen vorhanden Stege oder Erhöhungen unterbrechen.

Es bestände auch noch die Möglichkeit, die Innenfläche  
10 der Hülsen mit entlang der Rotationssymmetrieachsen der Hülse verlaufenden Rillen zu versehen.

Ferner könnte man eventuell ein Implantat mit einem zentralen Zapfen vorsehen, dessen eines Ende den Pfeiler  
15 und dessen anderes Ende eine hohle, zum Sockel gehörende Hülse bildet, von der bei einander diametral gegenüberstehenden Mantelstreifen Flügel wegragen, wobei diese und/oder die Hülse mit Löchern und zur Pfeilerachse parallelen, analog zu den Rillen 3c ausgebildeten Rillen  
20 versehen sein könnten. Ein solches Implantat könnte dann eine ähnliche Form besitzen, wie sie das Implantat 31 durch Abschneiden der äusseren Hülsen 33 und Anbringen der genannten Rillen am verbleibenden Zapfen-Teil 35a und/oder an den dann die Flügel bildenden Stegen 39 oder  
25 das Implantat 71 durch Anbringen der genannten Flügel erhielte.

Bei Implantaten, bei denen der Sockel mindestens zwei hohlzylindrische Teile aufweist und/oder bei denen der  
30 Sockel mit einer durch Plasmabeschichtung gebildeten, rauhen Oberfläche versehen ist, so dass der Sockel auch ohne Rillen ausreichend gut verankerbar ist, können die Rillen eventuell wegfallen.

PATENTANSPRÜCHE

1. Implantat zur Befestigung eines künstlichen Zahnersatzes (11) an einem Kiefer-Knochen (9), das einen zum  
5 Einsetzen in den letzteren bestimmten Sockel (7) und  
mindestens einen Pfeiler (5c) zum Halten des Zahnersatzes (11) aufweist, wobei der Sockel (7) mindestens  
zwei im allgemeinen kreiszyllindrische, hohle Teile (3)  
aufweist, deren Achsen parallel zueinander verlaufen und  
10 die an ihrem dem Pfeiler (5c) abgewandten Ende offen  
sind, dadurch gekennzeichnet, dass mindestens zwei der  
genannten, im allgemeinen kreiszyllindrischen Teile (3)  
auch an ihrem sich näher beim Pfeiler (5c) befindenden  
Ende vollständig offen sind.

15

2. Implantat nach Anspruch 1, dadurch gekennzeichnet,  
dass alle seine Teile starr und unlösbar miteinander  
verbunden sind, wobei das Implantat beispielsweise aus  
einem einstückigen Körper besteht, und dass der Mantel  
20 der im allgemeinen kreiszyllindrischen, beidseitig  
offenen Teile (3) mit Durchgangslöchern (3e) versehen  
ist und bei verschiedenen Umfangstellen über seine ganze  
Länge zusammenhängende Abschnitte aufweist.

25 3. Implantat nach Anspruch 1 oder 2, dadurch gekennzeichnet, dass der Sockel (7) ausschliesslich aus im  
allgemeinen kreiszyllindrischen Teilen (3,5a) besteht,  
deren Rotationssymmetrieachsen parallel zueinander ver-  
laufen und die einander tangieren oder einander durch-  
30 dringen und vorzugsweise alle hohl sowie mindestens an  
ihrem dem Pfeiler (5c) abgewandten Ende offen sind.

4. Implantat nach Anspruch 1 oder 2, dadurch gekennzeichnet, dass der Pfeiler (35c,45c) über Stege (39,49)  
35 mit den im allgemeinen kreiszyllindrischen Teilen (33,43)

verbunden ist.

5. Implantat zur Befestigung eines künstlichen Zahnersatzes (11,101) an einem Kiefer-Knochen (9,99), das  
5 einen zum Einsetzen in den letzteren bestimmten Sockel (7) und mindestens einem Pfeiler (5c,75) zum Halten des Zahnersatzes (11,101) aufweist, dadurch gekennzeichnet, dass mindestens ein Teil (3,73) des Sockels (7) mit Vertiefungen (3c,73c) und/ oder Erhöhungen versehen ist,  
10 die entlang von zur Achse des Pfeilers (5c,75) parallelen Geraden verlaufen oder angeordnet sind.

6. Implantat nach Anspruch 5, dadurch gekennzeichnet, dass der Sockel (7) mindestens einen hohlen, im allgemeinen zylindrischen Teil (3,73) aufweist, der an seinem  
15 dem Pfeiler (5c) abgewandten Ende offen ist und dessen Mantel an der Aussenfläche mit Vertiefungen (3c,73c) und/oder Erhöhungen der genannten Art versehen ist und dass der Mantel die Vertiefungen (3c,73c) und/oder Erhöhungen kreuzende Durchgangslöcher (3e,73e) aufweist.  
20

7. Implantat nach Anspruch 6, dadurch gekennzeichnet, dass mindestens zehn, und beispielsweise fünfzehn bis dreissig über den Umfang des im allgemeinen zylindrischen Teils (3,73) verteilte, die Vertiefungen bildende Rillen (3c,73c) vorhanden sind.  
25

8. Implantat nach Anspruch 6 oder 7, dadurch gekennzeichnet, dass die zwischen einer kreiszyklischen Schmiegefläche des hohlzylindrischen Teils (3,73) und  
30 der tiefsten Stelle einer Vertiefung (3c,73c) gemessene Tiefe (t) einer Vertiefung (3c,73c) bzw. die Höhe einer Erhöhung mindestens 20 % und vorzugsweise mindestens 30 % der maximalen Wandstärke (w) des Mantels beträgt und dass die Vertiefungen (3c,73c) und/oder Er-  
35

höhungen die betreffende Mantelfläche bezüglich der  
glatten Schmiegefläche um mindestens 50 % und bei-  
spielsweise um mindestens oder ungefähr 80 % ver-  
grössern.

5

9. Implantat nach einem der Ansprüche 5 bis 8, dadurch  
gekennzeichnet, dass die Vertiefungen durch Rillen  
(3c,73c) gebildet sind, deren eine Enden in die dem  
Pfeiler (5c,75) abgewandte Endfläche (3a,73a) des Sok-  
10 kels (7) münden und deren andere Enden durch Endflächen  
(3h) begrenzt sind.

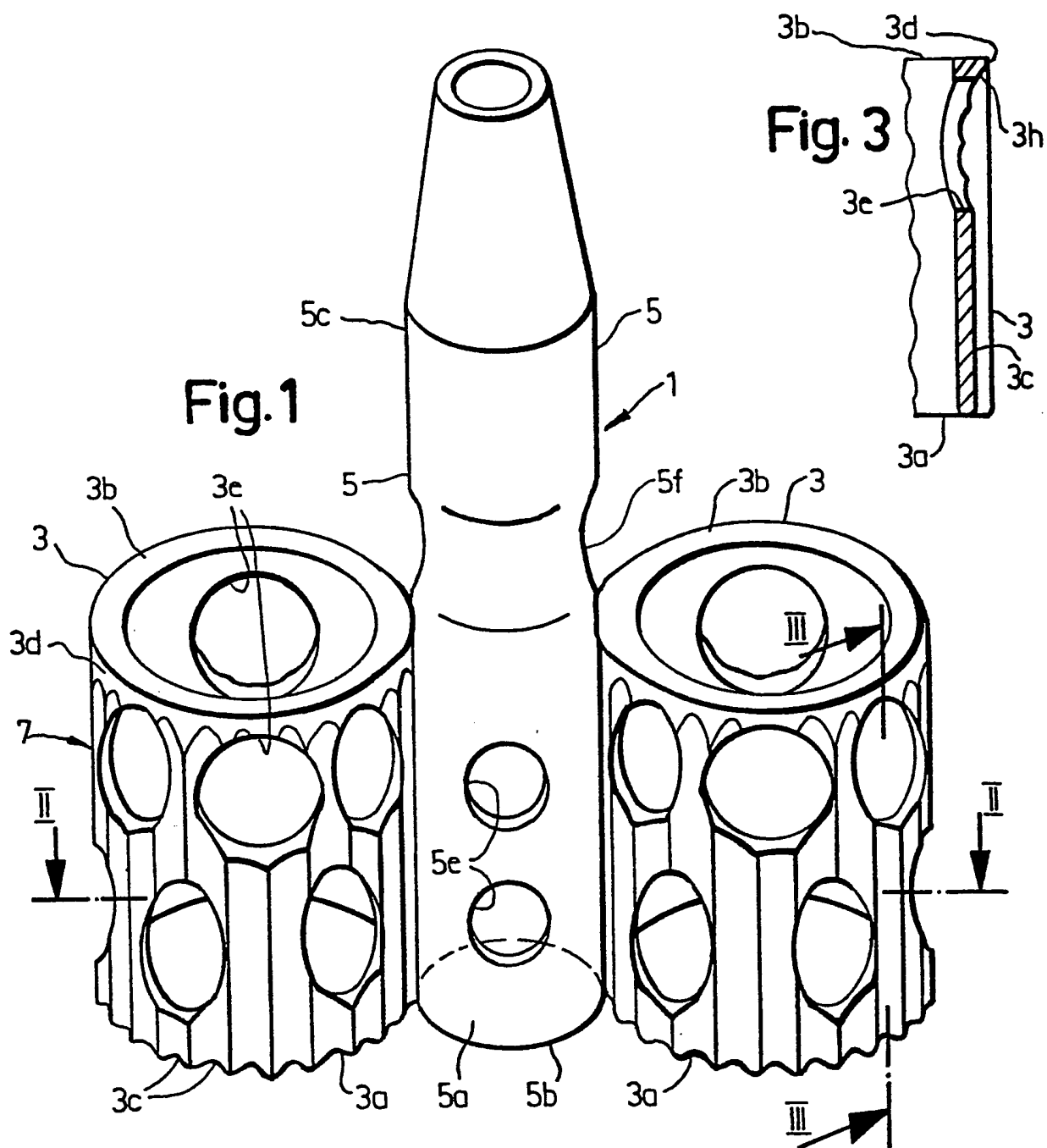
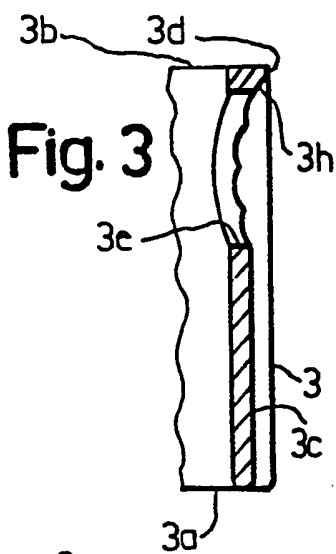
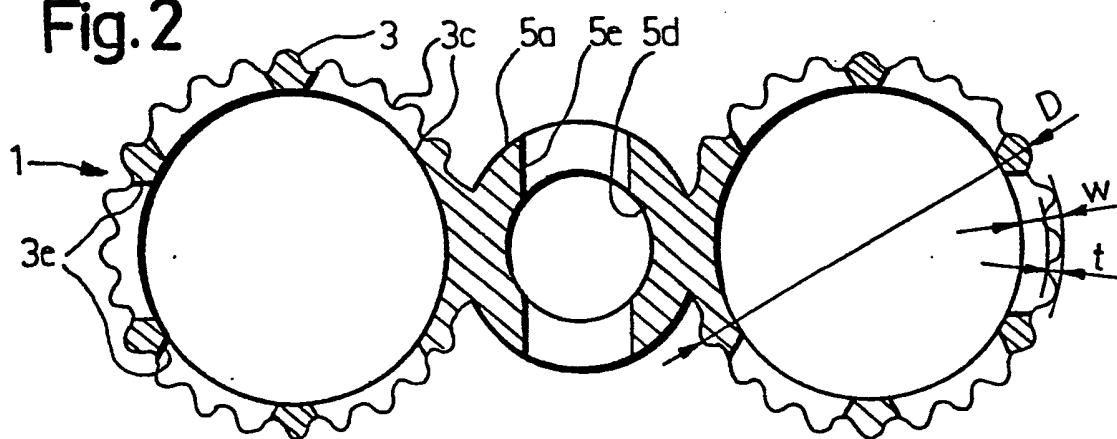
10. Implantat nach einem der Ansprüche 5 bis 9, dadurch  
gekennzeichnet, dass die Vertiefungen (3c,73c) sowie die  
15 sich dazwischen befindenden Erhöhungen und die Ueber-  
gänge zwischen den Vertiefungen (3c,73c) und Erhöhungen  
in einem zu Pfeiler-Längsrichtung rechtwinkligen Schnitt  
stetig verrundet sind.

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**Fig. 3****Fig. 2**

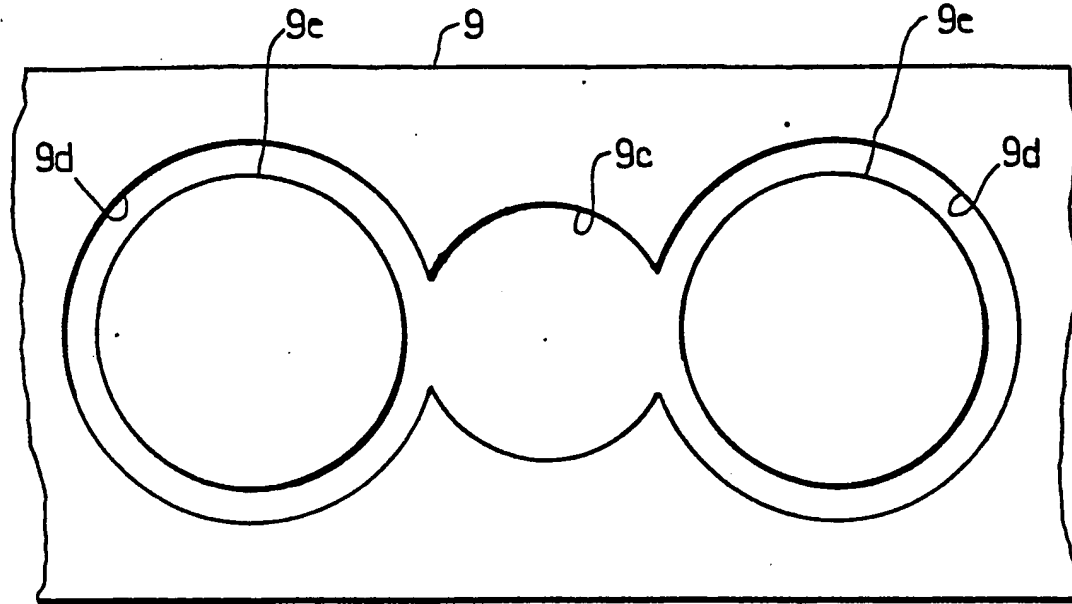


Fig. 4

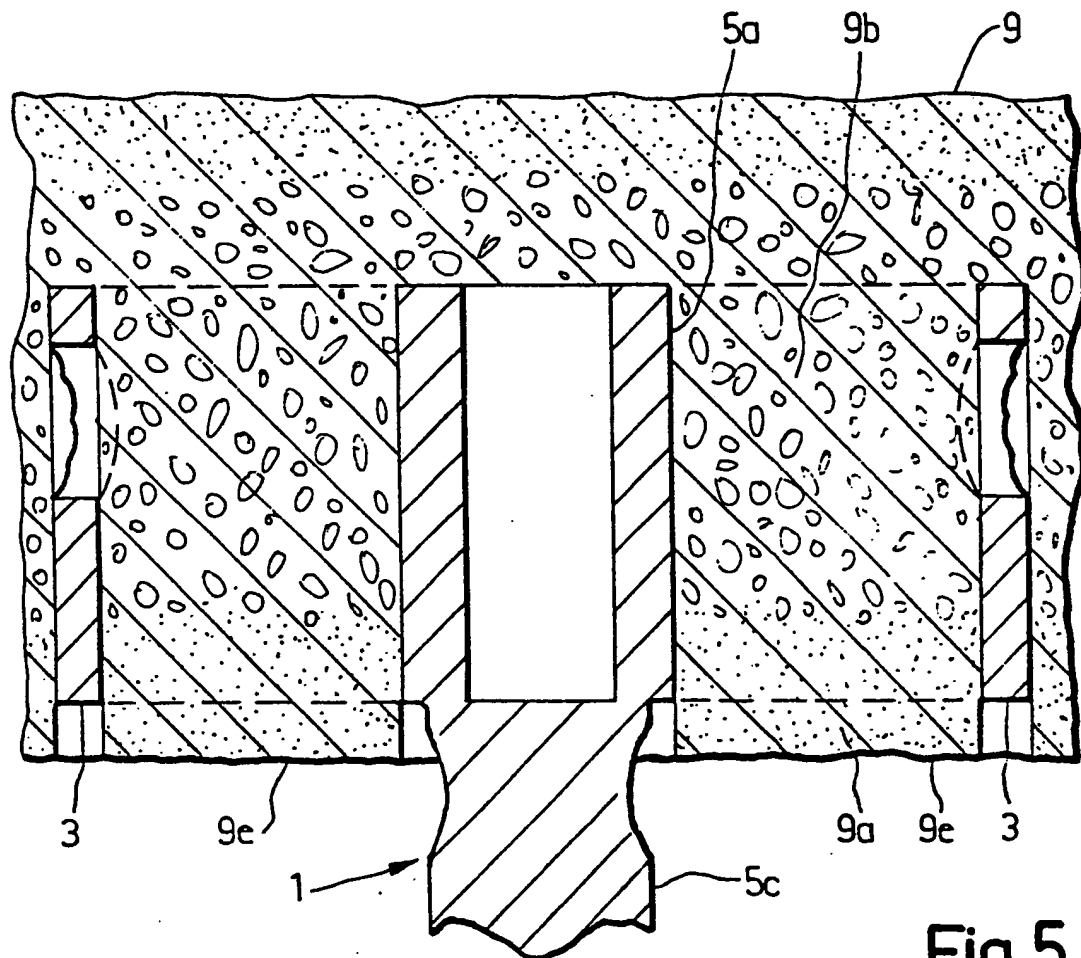


Fig. 5

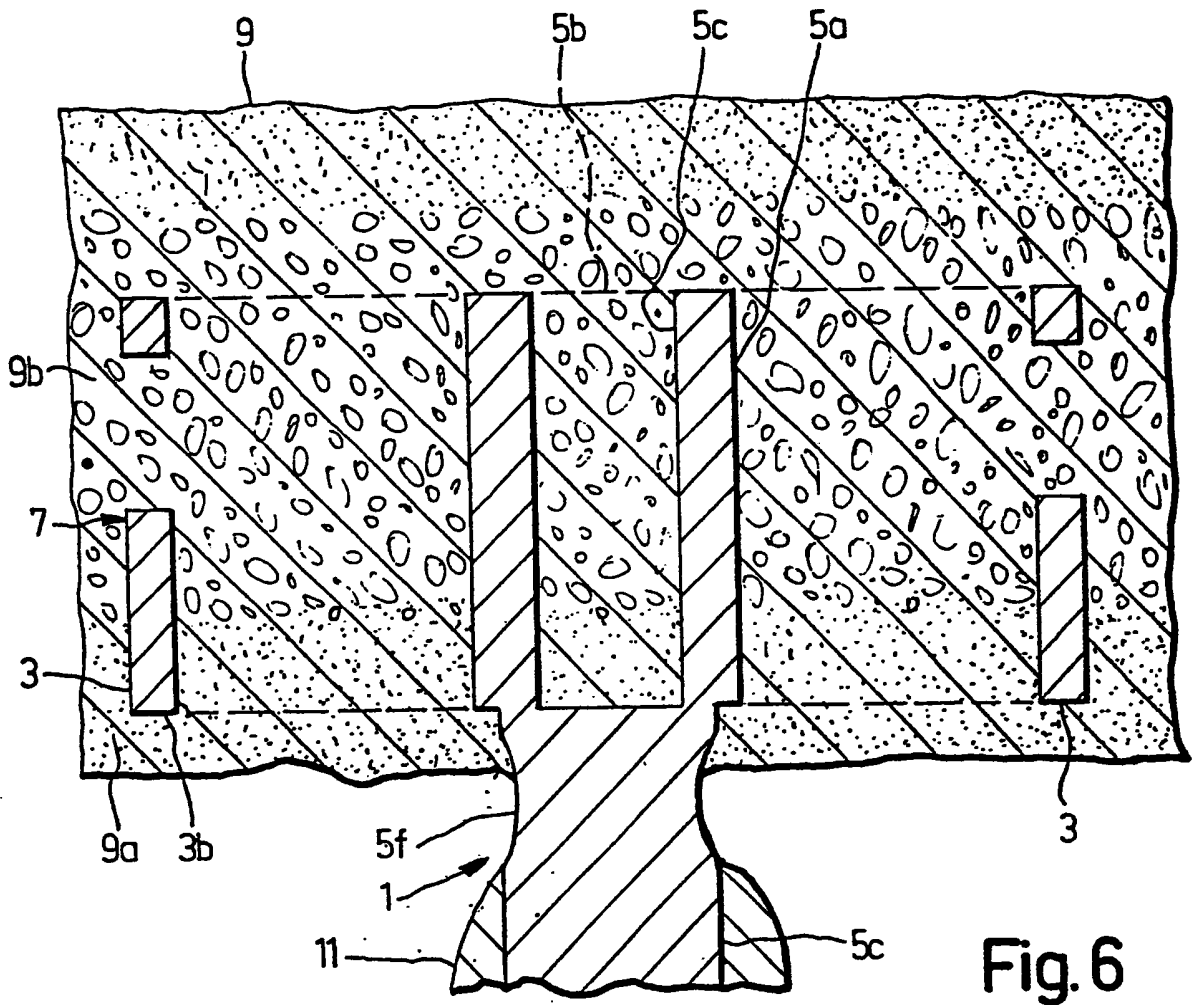


Fig. 6

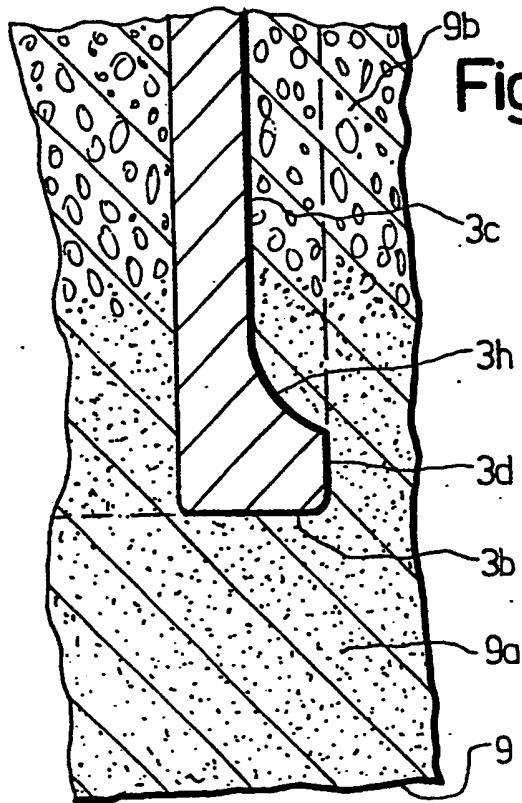


Fig. 7

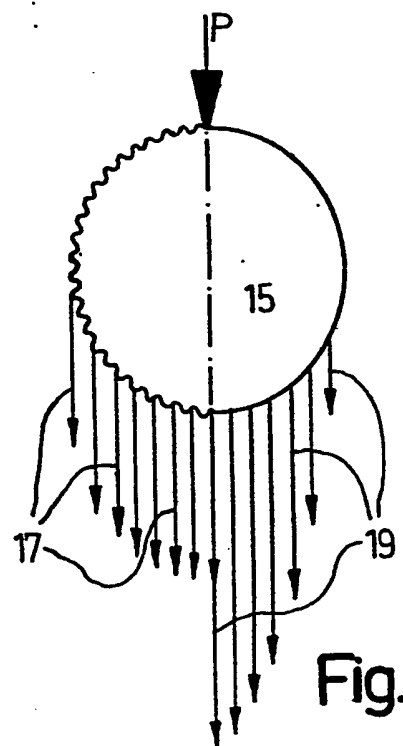


Fig. 8

Fig. 9

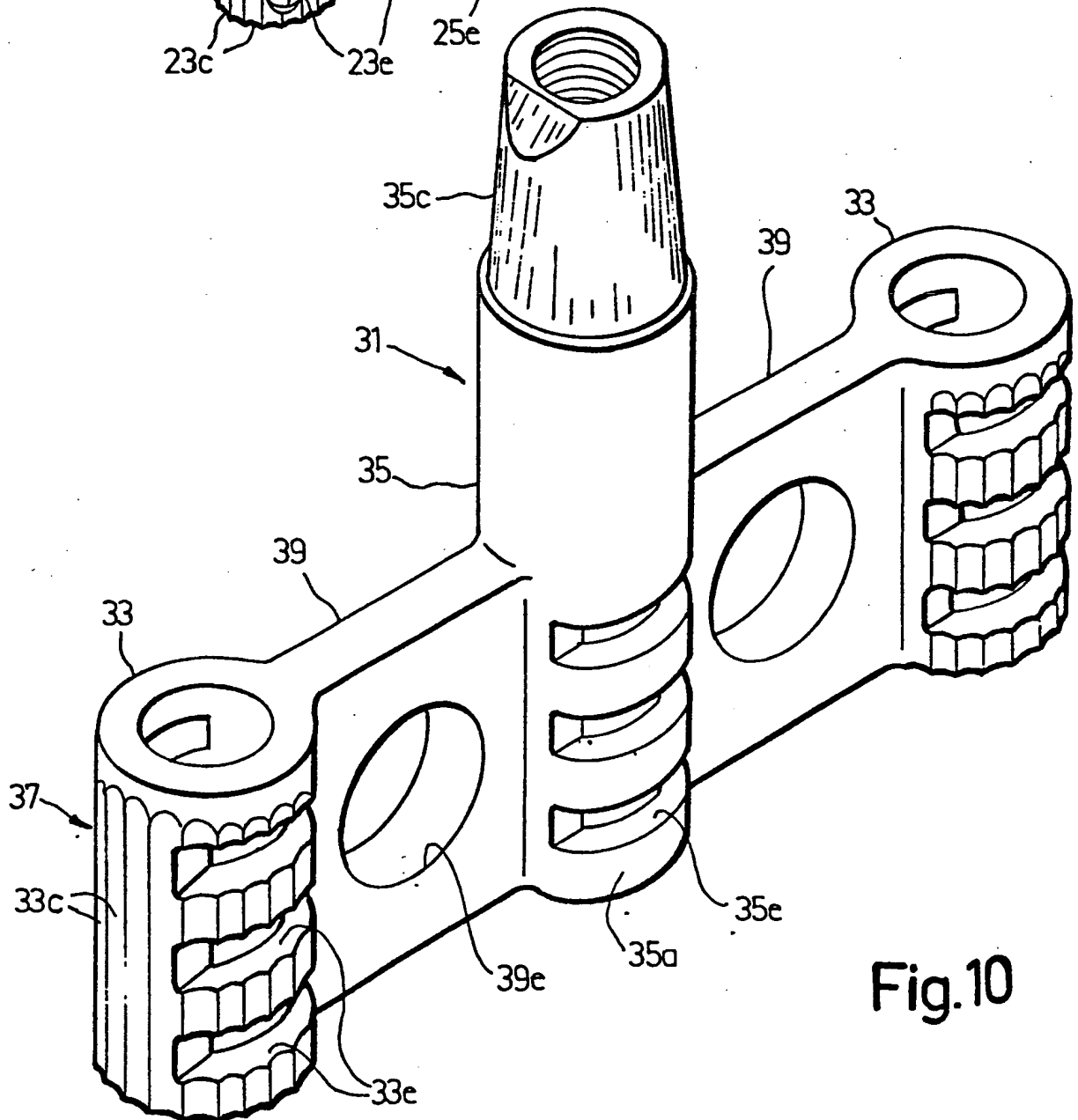
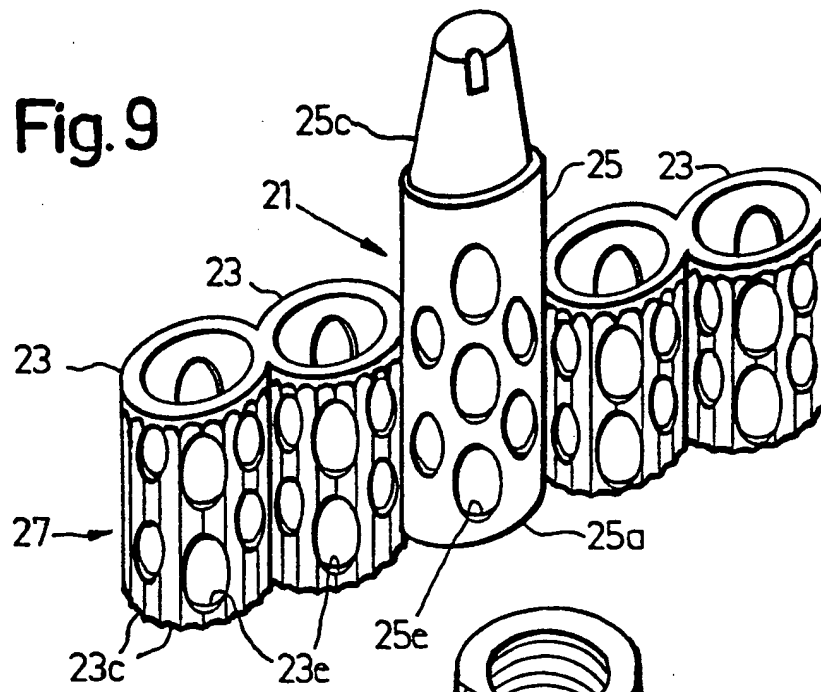


Fig. 10

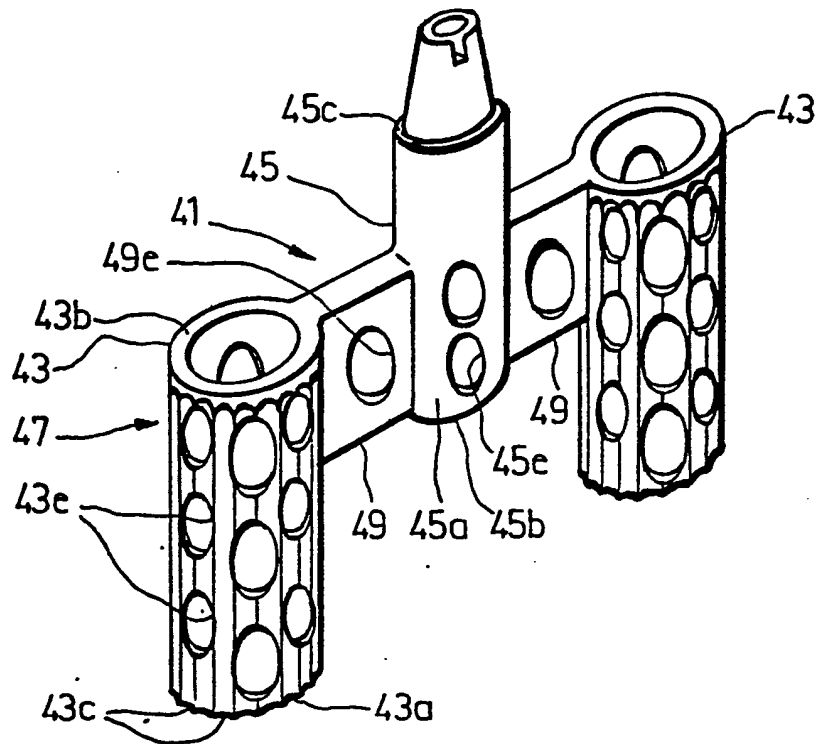


Fig.11

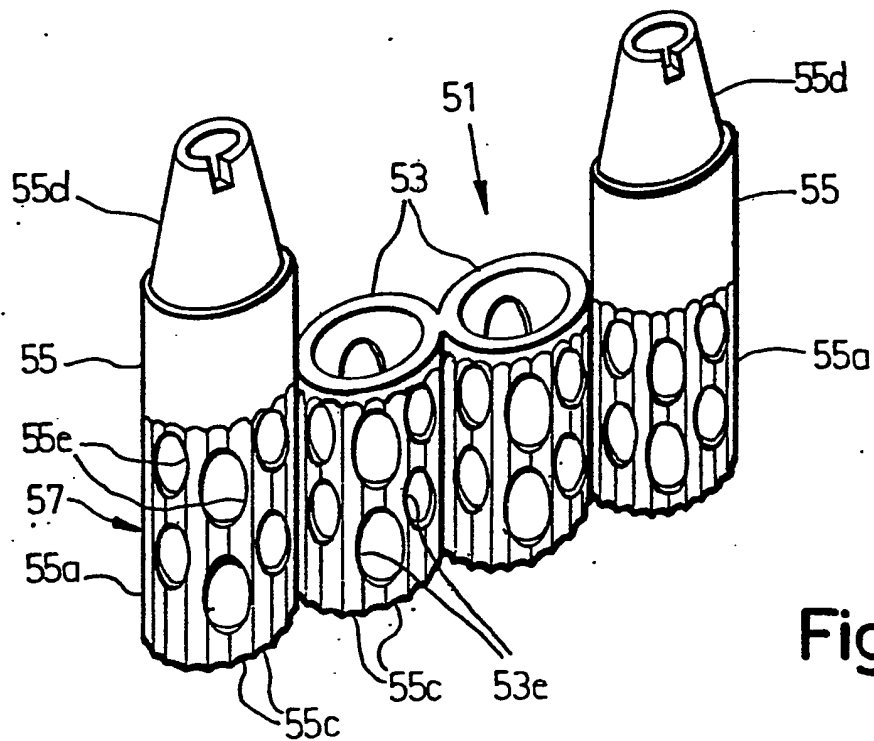


Fig.12

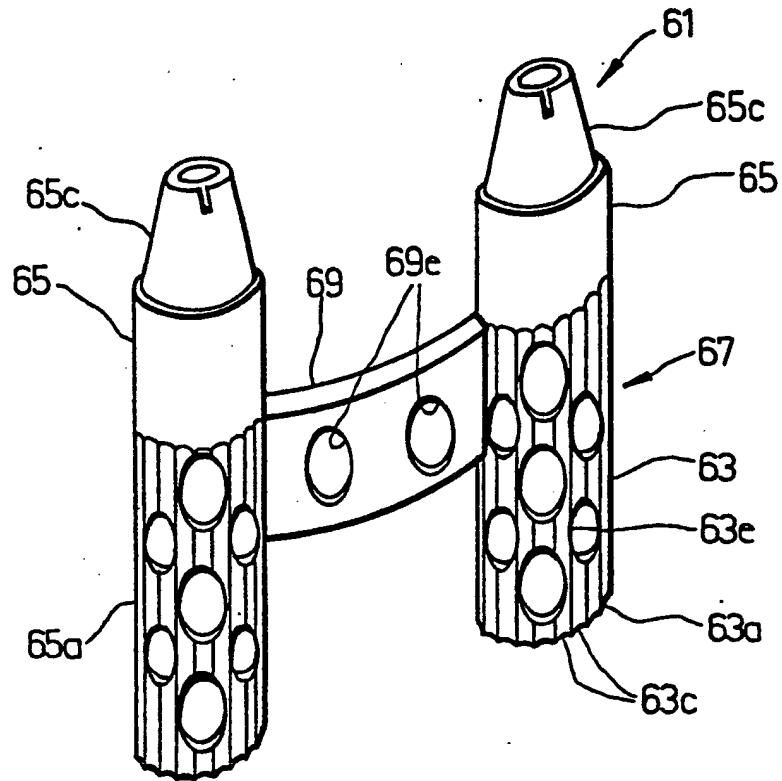


Fig. 13

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Fig. 14

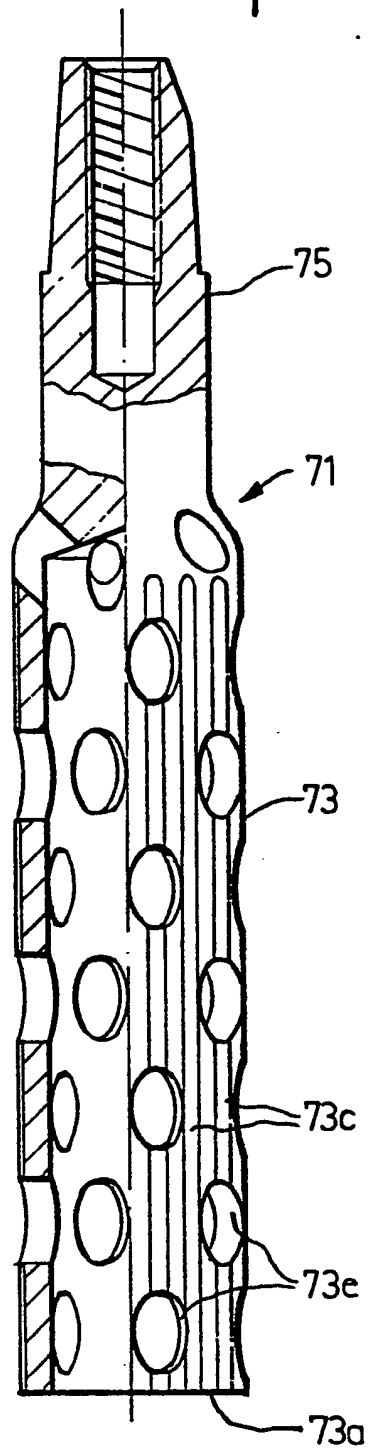


Fig. 15

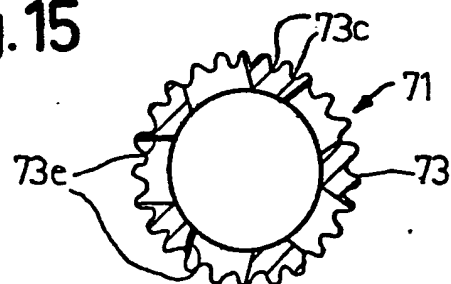


Fig. 16

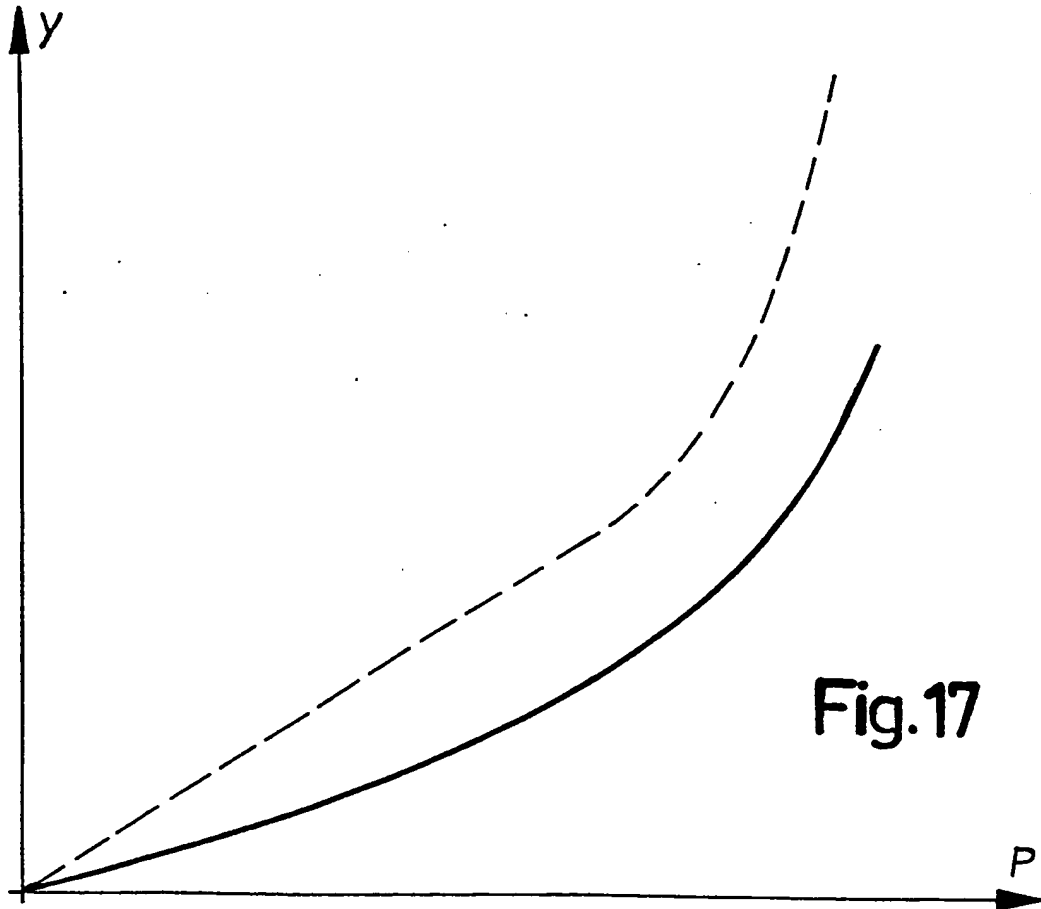
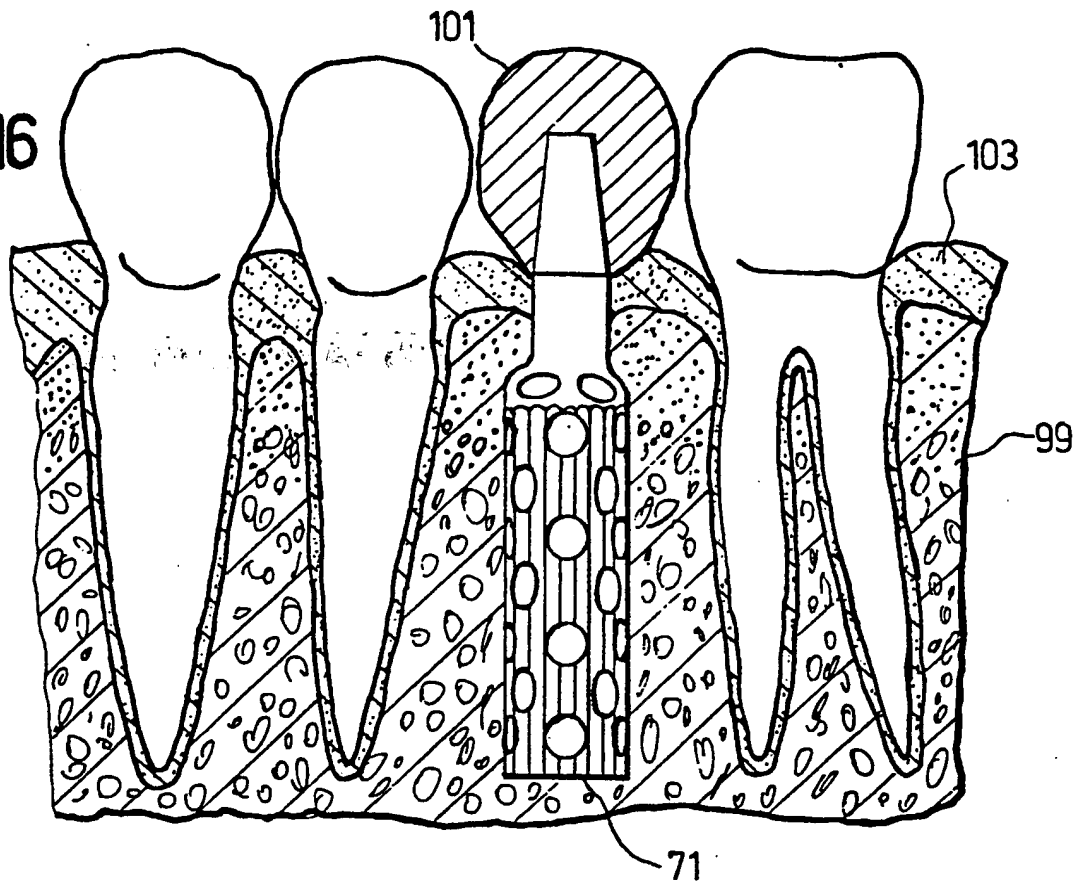


Fig. 17

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11 Veröffentlichungsnummer:

**0 073 177**  
**A3**

12

# EUROPÄISCHE PATENTANMELDUNG

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51 Int. Cl.<sup>3</sup>: **A 61 C 8/00**

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30 Priorität: 20.08.81 CH 5375/81

71 Anmelder: **INSTITUT STRAUMANN AG,**  
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43 Veröffentlichungstag der Anmeldung: 02.03.83  
Patentblatt 83/9

72 Erfinder: **Sutter, Franz, Bennwilerstrasse 42,**  
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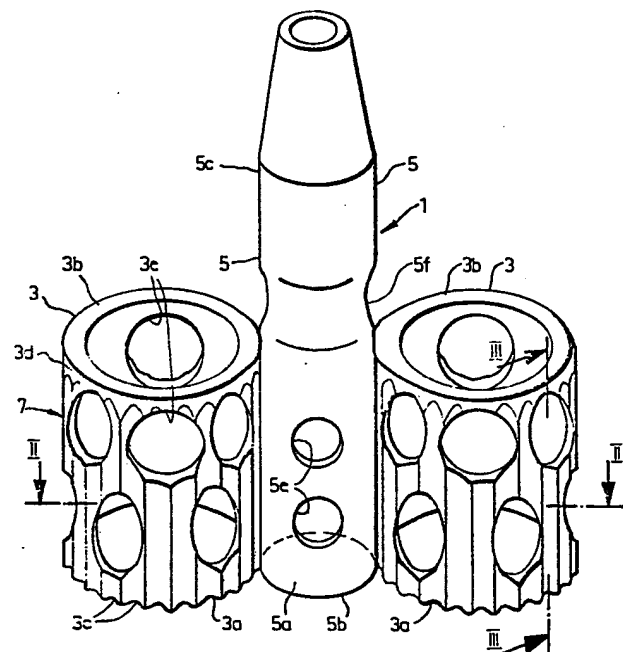
84 Benannte Vertragsstaaten: **DE FR GB IT SE**

88 Veröffentlichungstag des später veröffentlichten  
Recherchenberichts: 01.06.83 Patentblatt 83/22

74 Vertreter: **Eder, Carl E. et al, Patentanwaltsbüro Eder &**  
**Cie Münchensteinerstrasse 2, CH-4052 Basel (CH)**

54 **Implantat zur Befestigung eines künstlichen Zahnersatzes.**

57 Ein Implantat (1) weist einen zum Verankern in einem Kiefer-Knochen bestimmten Sockel (7) mit mindestens einer im allgemeinen kreiszylindrischen Hülse (3) und einen über den Sockel (7) vorstehenden Pfeiler (5c) zum Halten eines Zahnersatzes auf. Die Außenfläche der Hülse (3) ist mit über dem Umfang verteilten Rillen (3c) versehen. Diese erstrecken sich von der dem Pfeiler (5c) abgewandten Hülse-Endfläche (3a) nicht ganz bis zur andern Hülse-Endfläche (3b), so daß die Rillen dort durch Endflächen begrenzt werden, die bei einem in einem Kiefer eingesetzten Implantat (1) axiale Druckkräfte übertragen können. Ferner tragen die Rillen (3c) dazu bei, quer zur Pfeilerachse gerichtete, zu übertragende Kräfte gleichmäßig über den Hülse-Umfang zu verteilen. Wenn auch bei ihrem pfeilerseitigen Ende vollständig offene Hülsen (3) vorhanden sind, muß zum Überdecken der Hülsen (3) nur wenig Knochenmaterial nachwachsen.



EP 0 073 177 A3

EINSCHLÄGIGE DOKUMENTE			
Kategorie	Kennzeichnung des Dokuments mit Angabe, soweit erforderlich, der maßgeblichen Teile	Betrifft Anspruch	KLASSIFIKATION DER ANMELDUNG (Int. Cl. 3)
D, Y	CH - A - 618 870 (STRAUMANN) * Seite 4, Spalte 1, Zeilen 23 bis 43; Figuren 7,8 *	1,2	A 61 C 8/00
A	--	3	
Y	US - A - 4 177 562 (MILLER) * Spalte 3, Zeilen 62-64; Figur 4 *	1,2	
A	FR - A - 2 385 384 (PANTOMEDICAL GRIFO S.A.S. & STAFFOLANI) * Seite 6, Zeilen 21-37; Figuren 5,6 *	4	
Der vorliegende Recherchenbericht wurde für alle Patentansprüche erstellt.			RECHERCHIERTE SACHGEBIETE (Int. Cl. 3)
			A 61 C
Recherchenort Den Haag		Abschlußdatum der Recherche 18-10-1982	Prüfer VANRUNXT
<b>KATEGORIE DER GENANNTEN DOKUMENTEN</b> X : von besonderer Bedeutung allein betrachtet Y : von besonderer Bedeutung in Verbindung mit einer anderen Veröffentlichung derselben Kategorie A : technologischer Hintergrund O : nichtschriftliche Offenbarung P : Zwischenliteratur T : der Erfindung zugrunde liegende Theorien oder Grundsätze		E : älteres Patentdokument, das jedoch erst am oder nach dem Anmeldedatum veröffentlicht worden ist D : in der Anmeldung angeführtes Dokument L : aus andern Gründen angeführtes Dokument  & : Mitglied der gleichen Patentfamilie, übereinstimmendes Dokument	



## GEBÜHRENPFLICHTIGE PATENTANSPRÜCHE

Die vorliegende europäische Patentanmeldung enthielt bei Ihrer Einreichung mehr als zehn Patentansprüche.

- ☐ Alle Anspruchsgebühren wurden innerhalb der vorgeschriebenen Frist entrichtet. Der vorliegende europäische Recherchenbericht wurde für alle Patentansprüche erstellt.
- ☐ Nur ein Teil der Anspruchsgebühren wurde innerhalb der vorgeschriebenen Frist entrichtet. Der vorliegende europäische Recherchenbericht wurde für die ersten zehn sowie für jene Patentansprüche erstellt für die Anspruchsgebühren entrichtet wurden.
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## X MANGELNDE EINHEITLICHKEIT DER ERFINDUNG

Nach Auffassung der Recherchenabteilung entspricht die vorliegende europäische Patentanmeldung nicht den Anforderungen an die Einheitlichkeit der Erfindung; sie enthält mehrere Erfindungen oder Gruppen von Erfindungen, nämlich:

1. Patentansprüche 1-4 Implantat mit vollständig offenen kreiszylindrischen Teilen
2. Patentansprüche 5-10 Implantat mit über den Umfang verteilten Rillen.

- ☐ Alle weiteren Recherchegebühren wurden innerhalb der gesetzten Frist entrichtet. Der vorliegende europäische Recherchenbericht wurde für alle Patentansprüche erstellt.
- ☐ Nur ein Teil der weiteren Recherchegebühren wurde innerhalb der gesetzten Frist entrichtet. Der vorliegende europäische Recherchenbericht wurde für die Teile der Anmeldung erstellt die sich auf Erfindungen beziehen, für die Recherchegebühren entrichtet worden sind.
- nämlich Patentansprüche:
- ☒ Keine der weiteren Recherchegebühren wurde innerhalb der gesetzten Frist entrichtet. Der vorliegende europäische Recherchenbericht wurde für die Teile der Anmeldung erstellt, die sich auf die zuerst in den Patentansprüchen erwähnte Erfindung beziehen.
- nämlich Patentansprüche: 1-4.

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**EP 0 673 177 B1**

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## EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention  
of the grant of the patent:  
**02.05.2002 Bulletin 2002/18**

(51) Int Cl.7: **H04Q 7/36, H04Q 7/38**

(21) Application number: **95106798.2**

(22) Date of filing: **30.05.1989**

(54)

*[Faint, illegible text, possibly a stamp or signature]*

**EP 0 673 177 B1**

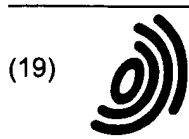
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(11) **EP 0 673 177 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

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(51) Int Cl.7: **H04Q 7/36, H04Q 7/38**

(21) Application number: **95106798.2**

(22) Date of filing: **30.05.1989**

(54) **Mobile telecommunications system using distributed miniature zones**

Mobiles Telekommunikationssystem mit verteilten Kleinzonen

Système de télécommunications mobiles utilisant des zones miniatures distribuées

(84) Designated Contracting States:  
**DE FR GB IT SE**

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**Tokyo 105 (JP)**

(30) Priority: **07.06.1988 JP 13840788**  
**09.06.1988 JP 14037488**  
**09.06.1988 JP 14037588**  
**09.06.1988 JP 14037688**  
**09.06.1988 JP 14037788**  
**09.06.1988 JP 14037888**  
**09.06.1988 JP 14037988**  
**10.06.1988 JP 14155088**  
**10.06.1988 JP 14155188**  
**10.06.1988 JP 14155388**

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(56) References cited:  
**US-A- 4 182 989**

(43) Date of publication of application:  
**20.09.1995 Bulletin 1995/38**

(62) Document number(s) of the earlier application(s) in  
accordance with Art. 76 EPC:  
**89109704.0 / 0 345 601**

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• **ELECTRONICS AND COMMUNICATIONS IN JAPAN, PART 1, vol. 72, no. 5, 1989 pages 87-95, XP 000085034 S.SAKAI ET AL. 'Communication Protocol for Vehicle Packet-Communication System Using Continuously Allocated Small Zones' & TRANSACTIONS OF THE INSTITUTE OF ELECTRONICS, INFORMATION AND COMMUNICATION ENGINEERS B, vol. 71B, March 1988 JAPAN, pages 383-390, S.SAKAI ET AL. 'Communication Protocol for Mobile Packet Communication System Using Continuously Allocated Small Zones'**  
• **FUNKSCHAU, no. 7, March 1984 MÜNCHEN DE, pages 57-59, DR. C. GRAUEL ET AL. 'Im 900-MHz-Band: Von Zelle zu Zelle. Neues Funktelefon am Beispiel erklärt.'**  
• **L'ONDE ELECTRIQUE, vol. 64, no. 3, 1984 PARIS, FR, pages 54-58, J.LAMY 'Télécommunications avec les mobiles'**  
• **TELECOMMUNICATION SWITCHING. STATE OF THE ART. IMPACT ON NETWORKS AND SERVICES. PROCEEDINGS OF THE INTERNATIONAL SWITCHING SYMPOSIUM ISS'84, vol. 3, 7 - 11 May 1984 FLORENCE IT, pages 32 B 4 1-32 B 4 7, T.GOTO ET AL. 'NATION-WIDE AUTOMOBILE TELEPHONE SERVICE USING NEW TRACKING EXCHANGE TECHNOLOGY'**

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## Description

### BACKGROUND OF THE INVENTION

#### Field of the Invention

[0001] The present invention relates to a mobile telecommunications system and, more particularly, to a mobile telecommunications system advantageously applicable, but not exclusively, to telecommunications with vehicles such as motorvehicles.

#### Description of the Prior Art

[0002] Typical of prior art mobile telecommunications systems with which the present invention is particularly concerned is an automobile telephone system which is disclosed in W. R. Young, "Advanced Mobile Phone Service", Bell Syst. Tech. J. Vol. 58, No. 1, pp. 1-278, Jan., 1979. Some of prior art automobile telephone systems share a cellular concept which is such that base stations each covering a limited service zone or cell are arranged two-dimensionally and the service zones of adjoining base stations overlap each other to insure the continuity of a communication.

[0003] To terminate an incoming call at a given mobile station, it is necessary to determine the current position of the mobile station. With the prior art cellular automobile telephone system, it has been customary to cause a network to access a plurality of zones by general calling, then detect a response of a mobile station of interest to determine the current position of the mobile station, and then terminate an incoming call at that station.

[0004] In a cellular mobile communication system, different frequencies are assigned to the individual zones or cells which adjoin each other so as to avoid interference of electromagnetic waves. To effectively use a limited frequency band available, it is preferable that the zone configuration is fractioned to promote repetitive use of the same frequency. However, fractioning the zone configuration increases the number of times that the frequency should be switched over during movement of a mobile station over a plurality of zones, forcing both of the base stations and the mobile stations to bear an extra load for frequency switchover control. This problem is more pronounced as the moving speed of a mobile body increases. The only implementation available with the prior art cellular system for eliminating this problem is to broaden each zone or to increase the number of frequencies assigned. However, increasing the number of frequencies is extremely difficult in the present severe frequency assignment environment.

[0005] An automobile telephone system implemented by the cellular concept is customarily designed to implement voice communications and is therefore not always suitable for services of the kind transmitting a large amount of data at high speed. In land traffic which involves automobiles, for example, services of the kind

mentioned include a navigation service which guides automobiles along appropriate routes depending upon the degrees of congestion, weather and so fourth, and an operation control service which controls the operations of a large number of automobiles collectively with efficiency. In this kind of traffic, therefore, a large amount of data have to be interchanged between on-board units and base stations at high speed. The frequency band of a transmit signal available with a prior art automobile telephone system is limited to the speech band, limiting the applicability of the system.

[0006] Further, in the prior art automobile telephone system, in response to every incoming call each base station accesses mobile stations by general calling and, after awaiting a response from a particular mobile station, terminates the call at that mobile station. This results in the need for complicated control over the termination of an incoming call and therefore in a relatively long connection setup time. With the prior art system, it is impossible to locate individual mobile bodies unless the mobile bodies are called up individually. It follows that a transport company or similar user owning a large number of vehicles cannot efficiently supervise the operations of the vehicles.

[0007] When a plurality of base stations each being communicatable with a mobile station over a radio link are distributed at spaced locations with a no-wave area intervening between nearby base stations, the base stations will be allowed to share the same frequency as the electromagnetic waves on the radio links. In a mobile communication system having such a configuration, the base station accessible to a mobile station sequentially changes as the mobile station travels and, hence, a communication with a desired mobile station cannot be adequately set up unless the system recognizes the varying position of the mobile station at all times. Moreover, even if the system accurately locates a mobile station at a certain moment, it is not warrantable that it actually stays in that position when a call meant therefore is originated. Especially, when it comes to a system applicable to ordinary roads as distinguished from thruways, a mobile body moves two-dimensionally so that estimating the future movement of a mobile body accurately so as to accomplish efficient call termination control is difficult. Moreover, it is undesirable that the traffic concentrates more on the communication which is adapted to locate mobile stations than on the primary communication traffic of the entire system.

[0008] In a mobile telecommunications system, mobile stations constantly move around without remaining in fixed positions so that a plurality of wave propagation paths exist between base stations and mobile stations. The wave propagation paths interfere with each other to cause sharp and noticeable changes in the amount of wave attenuation ascribable to the movement. Hence, in a blind area, a sufficient electromagnetic wave cannot be fed to a mobile station and it sometimes occurs that the path between a land station and a mobile

station cannot be set up despite that the land station is kept in connection to a switched telephone network. In this condition, an originating subscriber has to wait until the path to the mobile station has been set up and, in the meantime, the path between the calling terminal and the land station is held only ineffectively. When a predetermined period of time expires before the path between the land station and the mobile station is set up, the originating subscriber is informed of the unable-to-connect condition by, for example, a switched telephone network by voice. Then, the caller has to repetitively call the mobile station until the connection succeeds.

[0009] US-A-4 182 989 discloses a system for establishing a communication link between a ground station and each of vehicle drivers, wherein information is transferred in a compressed manner with respect to time while a vehicle moves within a limited communication area defined over a road surface by a UHV antenna. The peripheral units of the ground station are located in a series at intervals along a traffic lane. Therefore control of highways and city streets can be carried out, e.g. this system is exclusively applicable to a straight road.

[0010] The article "Von Zelle zu Zelle" in Funkschau, No. 7, March 1987, Munich, pages 57-59 discloses a cellular system which intends a continuous communication between cells. Thus, zones using different frequencies for data exchange are required to be partially overlapped.

[0011] The article "Communication protocol for mobile packet communication system using continuously allocated small zones" published in "Transaction of the Institute of Electronics, Information and communication engineers" B, Vol. 71 B, March 1988, Japan, pages 383-390, discloses a new vehicle communication system which is proposed to realize an excellent movement control of vehicles on highways. In this system, small communication zones of about 10 metres long are allocated continuously along the road, and every vehicle in the zone transmits and receives digital data through the same signal communication channel using the TDM.

#### SUMMARY OF THE INVENTION

[0012] It is therefore an object of the present invention to provide a new and useful mobile telecommunications system which implements high-speed telecommunications without occupying a number of frequencies.

[0013] It is another object of the present invention to provide a mobile telecommunications system which reduces the processing loads imposed on land stations and mobile stations while promoting effective use of a telecommunications network.

[0014] It is still another object of the present to provide a mobile telecommunications system which adequately supervises the conditions of mobile stations inclusive of communications with mobile stations.

[0015] It is yet another object of the present invention to provide, in a new mobile telecommunications system

capable of effecting high-speed telecommunications without occupying a number of frequencies, a call termination control system which enhances efficient control over the termination of a call at a desired mobile station.

[0016] It is a further object of the present invention to provide, in a new telemobile telecommunications system capable of effecting high-speed telecommunications without occupying a number of frequencies, a mobile station locating system which enables an originating subscriber to hold an adequate communication with a desired mobile station.

[0017] Present invention is defined in independent claim 1. In an embodiment of the present invention, there is provided a mobile telecommunications system comprising a plurality of base stations each being communicable with a mobile station over a radio link. The base stations are spaced apart from each other by an area in which the mobile station is substantially not responsive to an electromagnetic wave on the radio link and are therefore allowed to share a single frequency as the electromagnetic wave. A communication network accommodates the base stations and is constituted by a plurality of switching stations for switching communications to the base stations. The mobile station is registered in any one of the switching stations. Any one of the plurality of switching stations detected the mobile station reports the position of the mobile station to the switching station where the mobile station is registered. The switching station where the mobile station is registered stores data of the reported position of the mobile station. The switching station where the mobile station is registered constantly updates the stored position data in response to the position of the mobile station being detected and reported.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The objects and features of the present invention will become more apparent from the consideration of the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic block diagram showing a mobile telecommunications system using distributed miniature zones implemented as an on-road vehicle telecommunications system for road traffic;

FIG. 2 is a schematic block diagram representative of a specific hierarchical configuration of an on-road vehicle telecommunications network which is included in the system of FIG. 1;

FIG. 3 shows a specific format of a vehicle-oriented code applicable to the system of FIG. 1;

FIG. 4 indicates a specific frame format also applicable to the system of FIG. 1;

FIG. 5 is a diagram demonstrating a specific communication sequence between a mobile station and a roadside station included in the embodiment of

FIG. 1;

FIG. 6 is a view schematically showing a mobile telecommunications system using distributed miniature zones;

FIG. 7 is a schematic diagram representative of an alternative hierarchical configuration of the on-road vehicle telecommunications network;

FIG. 8 is a diagram demonstrating a specific sequence for locating a mobile station;

FIG. 9 is a diagram demonstrating a specific sequence for terminating a call at a mobile station;

FIG. 10 is a diagram schematically showing a specific paging group configuration of roadside stations;

FIG. 11 is a schematic block diagram representative of another specific hierarchical configuration of the on-road vehicle telecommunications network;

FIG. 12 indicates another specific format of the vehicle-oriented code;

FIG. 13 is a diagram schematically showing an embodiment of the present invention for detecting a roadside station located at the outgoing end of a coverage area;

FIG. 14 is a flowchart showing a procedure for a district station to report the position of a mobile station to a registry station in the embodiment of FIG. 13;

FIG. 15 is a flowchart demonstrating a specific procedure associated with an embodiment in which a message address is generated when a registry station terminates an incoming call at a mobile station;

FIG. 16 is a schematic view showing an alternative embodiment of the mobile telecommunications system using distributed miniature zones;

FIGS. 17A, 17B and 17C are schematic diagrams individually showing embodiments of single subordination and double-subordination of an end roadside stations which lies in the coverage area of a district station;

FIG. 18 is a schematic diagram showing an alternative embodiment of the mobile telecommunications system using distributed miniature zones in accordance with the present invention;

FIG. 19 is a block diagram schematically representative of an alternative hierarchical configuration of the on-road vehicle telecommunications network;

FIG. 20 is a flowchart associated with an embodiment of the present invention in which a message address is generated when a call is to be terminated at a mobile station;

FIG. 21 is a diagram schematically showing how a mobile station is called by adjacent district stations in the system shown in FIG. 18;

FIG. 22 is a schematic diagram showing how a mobile station is located in an alternative embodiment of the mobile telecommunications system using miniature zones in accordance with the present invention;

FIG. 23 is a chematic block diagram representative of an alternative hierarchical configuration of the on-road vehicle telecommunications network;

FIG. 24 is a diagram schematically indicating another specific sequence for locating a mobile station;

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0019]** Referring to FIG. 1 of the drawings, a mobile telecommunications system embodying the present invention is shown and implemented as an on-road vehicle telecommunications system applicable to land traffic, especially road traffic which involves automobiles and other similar vehicles. As shown, a plurality of base stations 10, in the following example referred to as roadside stations 10 are located along a road such as an ordinary road or a thruway at the intervals of several hundred meters or several kilometers, for example. The distance between nearby roadside stations 10 may be suitably selected in matching relation to the regulation speed of the road, for example. Each roadside station 10 is a land station which serves as a base station capable of communicating with a subscriber vehicle 12 over a radio channel.

**[0020]** Each roadside station 10 covers a limited service area or zone 20 and has a transmitter/receiver 14 for transmitting and receiving an electromagnetic wave 18 from an on-board unit, or mobile station, 16 (FIG. 2) which is mounted on a subscriber vehicle 12 that is present in the zone 20. A characteristic feature of the illustrative embodiment is that the roadside stations 10 are distributed at intervals and each zone 20 is far smaller than the interval between nearby roadside stations 10. The diameter of each zone 20 may be of the order of several ten meters to a hundred meters, for example. Therefore, the nearby zones 20 leave therebetween an area in which the mobile station 16 is substantially not responsive to any of the electromagnetic waves 18 issuing from the roadside stations 10, i. e. a no-wave area. A vehicle 12 can communicate with any of the roadside stations 10 only when it is operated within the zone 20 defined by the roadside station 10. This communication occurs at a high speed.

**[0021]** Having the above configuration, the illustrative embodiment allows the nearby roadside stations 10 to use the same frequency repetitively and effectively. Basically, therefore, the radio links between the roadside stations 10 and the mobile stations 16 included in the entire system can be implemented by a single frequency. A system with which full-duplex communication is available uses a pair of frequencies, one for an up-going channel and the other for a down-going channel. This eliminates the need for the switchover of frequency which is indispensable with the prior art cellular system. Having these characteristic features, the system will be referred to as a distributed miniature zone system while each zone 20 will be referred to as a minizture zone.

**[0022]** The roadside stations 10 form a part of an on-road vehicle telecommunications network, e.g. the communication system of the present example, 22 and, in this particular embodiment, they are capable of accessing a switched telephone network 24, a packet switching network or similar data switching network 25, or other similar telecommunications facilities such as a system center 26 and a user center 28 via the on-road vehicle telecommunications network 22. Adopting a hierarchical configuration as shown in FIG. 2 by way of example, the on-road vehicle telecommunications network 22 performs switching between the telephone network 24, data switching network 25 and centers 26 and 28 and the individual mobile stations 16, as described in detail later.

**[0023]** The distributed miniature zone telecommunications system described above promotes high-speed communication between the mobile stations 16 and the roadside stations 10 and, therefore, implements a variety of services including high-speed data communications. Typical examples are a navigation service for guiding an automobile or similar vehicle 12 along an adequate route which may depend on the degree of traffic congestion and weather, and a data communication service for allowing the mobile stations 16 to communicate with the center 26 or 28 via the telecommunications network 22 so that the operations of a great number of vehicles 12 may be managed efficiently.

**[0024]** Referring the FIG. 2, the hierarchy of the on-road vehicle telecommunications network 22 is constituted by district stations or offices 30 each accommodating a plurality of roadside stations 10 which are distributed in a certain district, regional stations or offices 32 each accommodating a plurality of district stations 30 over a certain area, and central stations 34 each accommodating a plurality of regional stations 32, wherein the district stations 30, the regional stations 32, and the central stations 34 can all be understood as switching stations in this present example. The associated stations 30, 32 and 34 inclusive of the roadside stations 10 will be collectively called a land station hereinafter. In the illustrative embodiment, the channels between the associated district station 30, regional station 32 and central station 34 are configured in a tree-like network which is constituted by basic trunks, transversal trunks or similar trunks 36. On the other hand, the central stations 34 are interconnected by a mesh type network. The present invention, of course, is not limited to such a network configuration and may be practiced with any other kind of hierarchy which matches with the nature of a road, e. g., an ordinary road or a thruway or a linear network.

**[0025]** The trunks 38 terminating at the switched telephone network 24 and data switching network 25 are accommodated in the central stations 34, for example. The system center 26 plays the role of a data processing system assigned to the navigation of the subscriber vehicles 12, for example. The user center 28 serves as a

data processing system available for a particular customer to supervise the operations of, among the subscriber vehicles 12, those which belong to the customer. The system center 26 and user center 28 are connected to the central stations 34 by trunks 40. These centers 26 and 28 may of course be connected to the regional centers 32 or the district centers 30.

**[0026]** The central station 34, regional station 32 and district station 30 have their own station codes. By representing the individual codes assigned to the central station 34 and regional station 32 by hierarchy, a registry land station code 52 (FIG. 3) is formed. For user owning a great number of subscriber vehicles, the district station code may be replaced with a user code which is particular to the user. The mobile station 16 mounted on each subscriber vehicle 12 is registered in any of the district station 32 and provided with a unique mobile station code 54 there. Hence, in the nationwide scale, each on-board unit or mobile station 16 is designated by a land station code 52 and a mobile station code 54. It is to be noted that the subscriber vehicles may be registered in the central stations or district stations.

**[0027]** As shown in FIG. 3, in the illustrative embodiment, a vehicle-oriented code for specifying a mobile station 16 is made up of a static code 50 and a dynamic code 60. The static code 50 specifies the mobile station 16 registered in the regional station 32 and consists of the land station code 52, the mobile station code 54 and a system code 56 adapted to distinguish the entire system from other systems. Specifically, the system code 56 identifies this system in distinction from the other systems and is omissible within this system. Hence, apart from the function of providing a mobile station 16 with an identification number within the system, the static code 50 is closely related to the number system of calls which the mobile station 16 may receive from the telephone network 24, data switching network 25 and centers 26 and 28.

**[0028]** The dynamic code 60 is associated with the moving state of the subscriber vehicle 12 and effectively used to grasp the current condition of the vehicle 12 for a navigating purpose. In this sense, the dynamic code 60 is a code unique to a subscriber vehicle 12 and associated with the district or region in which the vehicle 12 is operated as well as its travelling condition. The dynamic code 60, therefore, plays an important role in allowing any of the telephone network 24, data switching network 25 and centers 26 and 28 to locate a vehicle 12 for a paging purpose and supplying a vehicle 12 with guide information for routing it to a destination. In the illustrative embodiment, the dynamic code 60 includes a destination code 62 representative of a destination of the subscriber vehicle 12 and an first position information (64) hereafter referred to running area code 64 in this illustrative embodiment representative of an area in which the vehicle 12 and thereby the position of the mobile station 16 connected thereto is running. The running area code 64 is constituted by the codes which are in-

dividually assigned to the central station 34, regional station 32, and district station 30. The area code 64 may further include a link code which shows a communication link being set up.

**[0029]** As shown in FIG. 2, in the illustrative embodiment, the regional station 32 has a running vehicle table 80. The table 80 stores data representative of particular areas in which the subscriber vehicles 12 registered in the associated regional station 32 are running, on a station basis. The table 80 also stores data associated with other subscriber vehicles 12 which are running in the coverage area of the regional station 32, on a registry station basis. These data stored in the table 80 are updated every moment. A similar vehicle table may also be installed in each district station 30 or central station 34, as exemplarily indicated by a phantom line 84 in relation to the district station 30.

**[0030]** As FIG. 1 schematically indicates, each roadside station 10 has a memory 42 which includes areas for storing a passing vehicle table 82 (FIG. 2) and information to be interchanged between the roadside station 10 and the mobile stations 16. The passing vehicle table 82 holds data associated with the subscriber vehicles 12 which travel through the miniature zone 20 which the roadside station 10 covers. These data include the vehicle specific codes 50 and 60 and are constantly updated as the subscriber vehicles 12 pass through the miniature zone 20.

**[0031]** In the illustrative embodiment, the mobile station 16 is mounted on an automobile or similar subscriber vehicle 12 and transmits/receives navigation information, operation supervisory information and other similar data, messages and video signals with the roadside stations 10 while allowing an occupant to see such signals visually and/or auditorily. Preferably, the mobile station 16 is provided with a video display, facsimile transceiver, vocoder and other similar equipment for interfacing the roadside stations 10 to a vehicle occupant by means of pictures and speeches. Further, the mobile station 16 may be provided with an automatic operation control function which governs the steering mechanism of the subscriber vehicle 12. The mobile station 16 has a random number table function so that the road station 10 may select an idle channel out of a plurality of channels assigned to the link 18 between the stations 10 and 16 by polling.

**[0032]** In this embodiment, a communication between the on-board mobile station 16 and the base station 10 is effected by polling which uses a frame 100 having a format which is shown in FIG. 4. In the illustrative embodiment, the frame 100 has a period of 683 milliseconds (ms) and a signalling rate of 512 kilobits per second, a plurality of channels being multiplexed in a great number of time slots of the frame 100. In principle, a necessary bidirectional communication is completed within one frame period. The radio links 18 are implemented by a single frequency. In the case of full-duplex communication, each of an up-going and a down-going

channel is implemented by a different frequency. Nevertheless, since such frequencies are fixed, a subscriber vehicle 12 will be served by the same frequencies throughout the distributed zones 20 of the roadside stations 10. As shown in FIG. 4, the frame 100 is headed by an introductory field 102 which includes a preamble, a synchronizing signal, a polling identification (ID) signal, and a code assigned to a roadside station 10. As shown in FIG. 5, the roadside station 10 polls the mobile station 16 being operated in its own zone 20 at a predetermined period by using the introductory field 102 of the frame 100. The mobile station 16 is held in a receive mode while in an idle state and is brought into a transmit mode when the introductory field 102 is fully received.

**[0033]** The introductory field 102 is followed by a subscriber ID field 104 which allows the mobile station 16 to send its own vehicle codes 50 and 60 while allowing the roadside station 10 to recognize it. Advantageously, two blocks may be sent repetitively so as to achieve a far higher subscriber recognition rate. In response to the polling, the mobile station 16 selects an idle channel out of a plurality of channels by using the random number table. The static subscriber code 50 and a service function code are transmitted to the roadside station 10 over the idle channel (see FIG. 5).

**[0034]** In the illustrative embodiment, the subscriber ID field 104 is followed by a multicast communication field 106. By using this field 106 of the frame 100, the roadside station 10 sends to the mobile station 16 traffic information and other beacon type dynamic navigation information as well as registration response signal (ACK or NACK) (FIG. 5). If the channel selected by the mobile station 16 does not conflict with another channel, the roadside station 10 registers it and sends an ACK signal to the mobile station 16.

**[0035]** A vehicle communication field 108 is provided next to the multicast field 106 of the frame 100. In the illustrative embodiment, as shown in FIG. 5, a full-duplex communication is held between the roadside station 10 and the mobile station 16 by using the vehicle communication field 108. For the full-duplex communication, an up-going and a down-going channel each having a different frequency and selected by the roadside station 10 are used. However, the subscriber vehicle 12 is served by the same frequencies in the zones 20 which are defined by the nearby roadside stations 10. The full-duplex communication, of course, may be replaced with half-duplex or one-way communication. During the vehicle communication field 106, the mobile station 16 and the system center 26 and/or user center 28 interchange navigation information, operation supervisory information or similar data, message, and video signal. Such information is imparted to the vehicle occupant in the form of a picture or a speech. The mobile station 16 may communicate with any of the switched telephone network 24, data switching network 25, and another mobile station 16 which is served by this system, in the same manner as with the center 26 or 28.

**[0036]** The roadside station 10 may store in the passing vehicle table 82 the data associated with the subscriber vehicles 12 and obtained from the mobile stations 16 present in the zone 20 at each polling period. These data are sent from the roadside station 10 to the district station 30, regional station 32, or central station 34. The station 30, 32 or 34 then stores the incoming data in the running vehicle table 80, for example. Hence, the running vehicle table 80 of the regional station 32, for example, is constantly updated by new data.

**[0037]** Information sent from the center 26 or 28, switched telephone network 24 or data switching network 25 and meant for a certain mobile station 16 is temporarily stored in any of the stations, e. g. the memory 42 of the roadside station 10. The roadside station 10 compares a destination code associated with the information with the static vehicle codes 50 obtained from the mobile stations 16 which are present in the associated coverage area. If the destination code is coincident with any of the static vehicle codes 50, the roadside station 10 transmits the information stored in the memory 42 to the mobile station 16 for which the information is meant by using the down-going channel of the vehicle communication field 108 of the frame 100. Information sent from a certain mobile station 16 to the roadside station 10 is temporarily stored in the memory 42. The up-going information is transferred to the center 26 or 28, data switching network 25 or switched telephone network 24 over the on-road vehicle telecommunications network 22 later.

**[0038]** The vehicle communication field 108 of the frame 100 is followed by an end-of-communication field 110 for transmitting an up-going and a down-going answer signal (FIG. 5). This signal is adapted to confirm the end of communication and not to confirm the content of information.

**[0039]** By the above procedure, one frame 100 of communication is completed while the subscriber vehicle 12 runs through the service zone 20 which is managed by the roadside station 10. While the subscriber vehicle 12 runs in the no-wave area defined between two nearby zones 20, the mobile station 16 cannot communicate with the on-road vehicle communications network 22. Due to the use of a single frequency, the system may bring up the image of a conventional leakage coaxial cable broadcasting system. However, the illustrative embodiment is implemented as a one-to-one communication system and not a broadcasting system and is clearly distinguishable over a leakage coaxial cable broadcasting system due to the presence of no-wave areas.

**[0040]** In principle, this particular embodiment is constructed such that one communication completes while the subscriber vehicle 12 exists in a certain miniature zone 20. The roadside stations 10 are distributed along a road, whether it be an ordinary road or a thruway, at intervals which allow the subscriber vehicle 12 to complete a substantial amount of communications while run-

ning through some miniature zones 20 which have the no-wave areas therebetween. Stated another way, such a distant arrangement of roadside stations 10 makes it possible even for mobile stations 16 whose communication traffic is heavy to achieve desired communications satisfactorily.

**[0041]** Referring to FIG. 7, an alternative illustrative embodiment is shown in which the mobile stations 16 are individually registered in particular land stations beforehand, more specifically the on-road vehicle telecommunications network 22 of such an alternative embodiment. In this network 22, each mobile station 16 has a vehicle code generating unit 130 while each district station 30 has a station code generating unit 132. In the figure, similar components or structural elements are designated by the same reference numerals, and redundant description will be avoided for simplicity.

**[0042]** The vehicle code generating section 130 of the mobile station 16 generates a vehicle code which is assigned to the mobile station 16. The vehicle code includes a land station code 52 (FIG. 3) representative of a particular station in which the mobile station 16 is registered, and a mobile station code 54 assigned to the mobile station 16. These codes are set in the vehicle code generating section 130 and, in response to polling from any of the roadside stations 10, read thereout of to be transmitted.

**[0043]** As shown in FIG. 6, assume that a certain mobile station 16 is registered in one,  $B_1$ , of regional stations which are subordinate to a central station  $A_1$ . Further, assume that the land station code 52 assigned to the regional station 32 is " $A_1B_1$ ", and the mobile station code 54 assigned to the mobile station 16 within the regional station 32 is " $M_{03}$ ". Then, the mobile station 16 is designated by a static vehicle code " $A_1B_1M_{03}$ ".

**[0044]** Given one,  $C_1$ , of the district stations belonging to the regional station  $A_0B_1$  accommodates eight roadside stations 10 which are designated by station codes  $D_0$  to  $D_7$ , respectively, the sixth roadside station 10 as counted from the left in FIG. 6 is designated by a station code " $A_0B_1C_1D_5$ ". When the mobile station 16 whose static vehicle code 50 is " $A_1B_1M_{03}$ " is polled by the roadside station  $A_0B_1C_1D_5$  while running through the zone 20 of that roadside station, the mobile station 16 returns an ID code " $A_1B_1M_{03}$ " to the roadside station  $A_0B_1C_1D_5$  as the roadside station code 52 and mobile station code 54.

**[0045]** As the mobile station 16 running in a direction indicated by an arrow in the figure enters the zone 20 as defined by the next roadside station  $A_0B_1C_1D_6$ , it is again polled by the roadside station  $A_0B_1C_1D_6$  and, in response, returns its vehicle code " $A_1B_1M_{03}$ ". In this manner, as the mobile station  $A_1B_1M_{03}$  moves in a particular direction, the successive roadside stations 10 on the route sequentially receives the vehicle code " $A_1B_1M_{03}$ " from the mobile station  $A_1B_1M_{03}$ .

**[0046]** More specifically, as shown in FIG. 7, the district station 30 of this embodiment has a station code

generating unit 132 for generating a land station code 52 which designates the district station 30 and a roadside station code which designates a roadside station subordinate to the station 30. For example, the district station  $A_0B_1C_1$  shown in FIG. 6 has a land station code " $A_0B_1C_1$ " set in its station code generating unit 132. The vehicle code " $A_1B_1M_{03}$ " of the mobile station 16 received by the roadside station  $A_0B_1C_1D_5$  is once stored in the passing vehicle table 82 (FIG. 7) while being transferred to the district station, or upper layer station,  $A_0B_1C_1$ . As shown in FIG. 8, as the district station  $A_0B_1C_1$  determines that the mobile station 16 with the vehicle code " $A_1B_1M_{03}$ " is registered in the regional station  $A_1B_1$  which in turn is subordinate to the central station  $A_1$  as indicated by the vehicle code " $A_1B_1M_{03}$ ", it transfers the vehicle code " $A_1B_1M_{03}$ " to the regional station  $A_1B_1$ . The district station  $A_0B_1C_1$  also sends to the regional station  $A_1B_1$  information representative of its own position and a position of the roadside station 10 which has detected the mobile station 10, i. e. information indicative of the current position of the mobile station 16. This position information includes the land station code " $A_0B_1C_1$ " and roadside station code " $D_5$ " as the running area code 64 of the dynamic vehicle code 60.

**[0047]** Switching stations lying above the district station  $A_0B_1C_1$  such as the regional station  $A_0B_1$  and central stations  $A_0$  and  $A_1$  determine the destination of the mobile station position data on the basis of the vehicle code " $A_1B_1M_{03}$ " and then repeats it to the station in which the mobile station 16 is registered (hereinafter referred to as a registry station for convenience), i. e. the regional station  $A_1B_1$  in this example. Receiving the mobile station position data in the form of the static vehicle code 50 and dynamic vehicle code 60, the registry station  $A_1B_1$  identifies the mobile station 16 of interest, i. e., the mobile station  $M_{03}$  as represented by the mobile station code 54 and then stores the position data in a particular location of the running vehicle table 80 which is allocated to the station  $M_{03}$ .

**[0048]** The current position data associated with the mobile station 16 is constantly updated. In this particular embodiment, every time any of the roadside stations 10 detects a mobile station such as  $M_{03}$ , the arrival is reported from the district station 30 to the registry station  $A_1B_1$  in which the mobile station  $M_{03}$  is registered. This updates the running vehicle table 80 of the registry station  $A_1B_1$  as to the mobile station  $M_{03}$ .

**[0049]** In the illustrative embodiment, every time the mobile station 16 travels over two consecutive roadside stations 10, its position is reported to the registry station where it is registered. The current position data to be sent to the registry station may include a roadside station code, i. e. " $D_5$ " in this example. Assuming that the mobile station  $A_1B_1M_{03}$  has moved away from the miniature zone 20 of the roadside station  $A_0B_1C_1D_5$  to the miniature zone 20 of next roadside station  $A_0B_1C_1D_6$ , then the station  $A_0B_1C_1D_6$  detects it by polling, stores

the mobile station code " $A_1B_1M_{03}$ " in the passing vehicle table 82, and reports it to the district station  $A_0B_1C_1$ . In response, the district station  $A_0B_1C_1$  informs the registry station  $A_1B_1$  of the new position of the mobile station  $A_1B_1M_{03}$  by using a running area code " $A_0B_1C_1D_6$ " which includes the roadside station code " $D_6$ ". While this kind of system needs a relatively large amount of communication traffic for reporting the current position of the mobile station 16 and imposes relatively heavy updating and storing loads on the registry station, it is capable of measuring the varying position of the mobile station 16 with accuracy at all times.

**[0050]** Alternatively, an arrangement may be made such that when any of the district stations 30 has detected the particular mobile station  $M_{03}$  for the first time through any of its associated roadside stations 10, the arrival is reported to the registry station  $A_1B_1$  where the mobile station  $M_{03}$  is registered. In this case, the running area code 64 (FIG. 3) does not have to include the roadside station code. Specifically, assume that the mobile station  $A_1B_1M_{03}$  has moved away from the last roadside station  $A_0B_1C_1D_7$  subordinate to the district station  $A_0B_1C_1$  to the zone 20 which is defined by the first roadside station  $A_0B_1C_2D_0$  of the next district station  $A_0B_1C_2$ . Then, the roadside station  $A_0B_1C_2D_0$  reports the vehicle code 50 of the mobile station  $A_1B_1M_{03}$  to the district station  $A_0B_1C_2$  which then registers it in the passing vehicle table 82. At this instant, the district station  $A_0B_1C_2$  checks the passing vehicle table 82 to see if the vehicle code " $A_1B_1M_{03}$ " has been stored in the table 82 in the past. If it has not been stored in the table 82, the district station  $A_0B_1C_2$  transfers the current position data of the mobile station  $A_1B_1M_{03}$  to the registry station  $A_1B_1$  via the associated regional station  $A_0B_1$ . Here, the station code " $A_0B_1C_2$ " which ends with the district station code suffices for the current position data. This alternative system is practicable with a minimum of communication traffic for reporting the current position of the mobile station 16, while simplifying the supervisory procedure required of the registry station.

**[0051]** A reference will be made to FIG. 9 for outlining a sequence available with this particular embodiment to allow a call from the center 26 or 28 to arrive at the mobile station  $A_1B_1M_{03}$  by using the mobile station position data which is constantly updated by the registry station  $A_1B_1$ . A message destined to the mobile station  $A_1B_1M_{03}$  is sent from the center 26 or 28 to the registry station  $A_1B_1$  via the central station 34, together with a header in the form of a static vehicle specific code 50 which includes a destination code " $A_1B_1M_{03}$ ". This message transfer is effected by causing each transit or tandem station to identify the destination code " $A_1B_1M_{03}$ ". On reception of the message together with the header, the registry station  $A_1B_1$  determines whether or not the destination or mobile station  $A_1B_1M_{03}$  is qualified as to the registration on the basis of the destination code and, if it is qualified, temporarily stores the message in a memory (not shown) (140). Although not shown in the

figure, the registry station  $A_1B_1$  returns an answer for confirmation to the center 26 or 28.

[0052] Then, the registry station  $A_1B_1$  references the running vehicle table 80 to determine the current position of the mobile station  $A_1B_1M_{03}$  which is represented by the mobile station position data. When the registry station  $A_1B_1$  decides that the mobile station  $A_1B_1M_{03}$  is currently located at " $A_0B_1C_1D_5$ ", for example, it generates a dynamic vehicle specific code 60 in which the address " $A_0B_1C_1$ " of the district station 30 is included as the running district code 64. The registry station  $A_1B_1$  reads the message out of its memory, adds it to the header of the dynamic code 60, and transmits the dynamic code 60 with such a header to the district station  $A_0B_1C_1$ .

[0053] Transit stations such as the central and regional stations 34 and 32 identify the dynamic vehicle code 60 of the message and transfer it to the district station  $A_0B_1C_1$ . On reception of the message with the header, the district station  $A_0B_1C_1$  accesses all of its subordinate roadside stations 10 at the same time by a send request, the message, and the destination code " $A_1B_1M_{03}$ " to which the message is destined. In response, each roadside station 10 once stores the message in the memory 42 and polls mobile stations 16 which are present in its service zone 20. This polling is effected by using the introductory field 102 of the frame 100, as stated earlier.

[0054] In response to the polling, active mobile stations 16 present in the service zone 20 which is defined by the roadside station 10 generate the vehicle codes 50 and 60 (FIG. 3) by the individual vehicle code generating units 130 and return them to the roadside station 10. This is implemented by the vehicle ID field 104 (FIG. 4) of the frame 100. The roadside station 10 temporarily stores the vehicle codes returned from the mobile stations 16 and compares the individual static vehicle codes 50 with the destination code " $A_1B_1M_{03}$ " (142). When any of the static vehicle codes coincides with the destination code at a certain roadside station 10, that roadside station 10 reads the message out of its memory 42 and sends it over the channel of the mobile station  $A_1B_1M_{03}$  by using the vehicle communication field 108 of the frame 100. The mobile station  $A_1B_1M_{03}$  received the message returns an answer for confirmation to the roadside station 10 by using the end-of-communication field 110 of the frame, the answer being finally transferred to the registry station 32. If the answer includes a positive response ACK, the district station  $A_0B_1C_1$  cancels the send request to the other roadside stations 10.

[0055] The other roadside stations 10 where the coincidence of the two different kinds of codes has not occurred discard the message stored in their memories 42 and end this processing, under the control of the district station  $A_0B_1C_1$ . While the individual stations return a confirmation signal at each step of the sequence described above, such a procedure is not shown in FIG. 9

to avoid intricacy of illustration.

[0056] In summary, in this particular embodiment, the mobile stations 16 are individually registered in particular land stations. A land station detected a mobile station 16 which is registered in a particular land station reports the current position of the station 16 to the latter land station to allow it to store the current position data. The current position data is constantly updated on a real time basis. When a certain mobile station 16 is to receive a call, a registry station where the mobile station 16 is registered is accessed to see the current position of the mobile station 16. The mobile station 16, therefore, is connected to any of the roadside stations 10 which is adjacent to the current position of the mobile station 16.

[0057] To efficiently control the termination of a call at a mobile station 16, a plurality of roadside stations 10 may be constructed into a paging group on the basis of their locations, as described hereinafter. In this alternative illustrative embodiment, a paging is effected by handling the group as a unit. The group configuration may be such that all the roadside stations 10 belonging to a single district station 30 constitute a paging group. Alternatively, some of the roadside stations 10 which are subordinate to the same district station 30 and geographically adjacent to each other may be treated as a paging group. An alternative embodiment of the telecommunications network 22 for implementing the second-mentioned paging group configuration is shown in FIG. 11. In the figure, the district station 30 has a roadside station table 134 which stores which of the roadside stations 10 in the coverage area belong to which paging group. The table 134 is referenced when a paging is to be effected for the termination of a call at a mobile station 16.

[0058] As shown in FIG. 10, when the mobile station  $A_1B_1M_{03}$  is operated on an ordinary road 136 toward a crossroad 138 by way of example, there are three different directions which the mobile station  $A_1B_1M_{03}$  may travel via the crossroad 138. For example, assume that the mobile station  $A_1B_1M_{03}$  is running in the coverage area of the roadside station  $A_0B_1C_1D_5$  and, therefore, the current position " $A_0B_1C_1D_5$ " of the mobile station  $A_1B_1M_{03}$  is stored in the running vehicle table 80 of the registry station  $A_1B_1$ . When the current position " $A_0B_1C_1D_5$ " of the mobile station  $A_1B_1M_{03}$  is determined by referencing the running vehicle table 80 and, based on this position, the mobile station  $A_1B_1M_{03}$  is called via the roadside station  $A_0B_1C_1D_5$ , the termination of the incoming call at the station  $A_1B_1M_{03}$  often fails because the probability that the station  $A_1B_1M_{03}$  has already moved away from the service zone 20 of the roadside station  $D_5$  is great. The route which the mobile station  $A_1B_1M_{03}$  moved away from the service zone 20 may take is indefinite, as shown in the figure.

[0059] To eliminate the above problem, this particular embodiment arranges the roadside stations 10 in a paging group configuration. In the example shown in FIG. 10, the roadside stations  $D_2$ ,  $D_3$ ,  $D_4$ ,  $D_5$  and  $D_6$  which

geographically adjoin each other around the road 136 are accommodated in a single district station 30 to constitute a single paging group. This group is listed in the roadside station table 134 of the district station  $A_0B_1C_1$ . If desired, only the roadside stations  $D_3$ ,  $D_4$  and  $D_6$  may be constructed into a group.

**[0060]** Again, a reference will be made to FIG. 9 for describing a sequence available with this particular embodiment to terminate a call from the center 26 or 28 at a mobile station  $A_1B_1M_{03}$  on the basis of the mobile station position data which is constantly updated at the registry station  $A_1B_1$ . As stated previously, a message to be sent from the center 26 or 28 to the mobile station  $A_1B_1M_{03}$  is transmitted to the registry station  $A_1B_1$  via the central station 34, together with a header in the form of the static vehicle code 50 which includes the destination code " $A_1B_1M_{03}$ ". For so transferring the message, the transit stations individually identifies the destination code " $A_1B_1M_{03}$ " of the message. On reception of the message with the header, the registry station  $A_1B_1$  checks the destination code to see if the mobile station  $A_1B_1M_{03}$  is a registered or qualified station and, if it is qualified, temporarily stores the message in a memory (not shown) (140). At this instant, the station  $A_1B_1$  returns a confirmation signal to the center 26 or 28, although not shown in the figure.

**[0061]** Then, the registry station  $A_1B_1$  references the running vehicle table 80 to determine the current position of the mobile station  $A_1B_1M_{03}$  on the basis of the mobile station position data being stored in the table 80. In the illustrative embodiment, if the current position is " $A_0B_1C_1D_5$ " by way of example as determined by the registry station  $A_1B_1$ , the registry station  $A_1B_1$  produces a dynamic vehicle specific code 60 which includes the address " $A_0B_1C_1D_5$ " of the roadside station 10 as the running area code 64 (FIG. 3). The registry station  $A_1B_1$  reads the message out of the memory, adds the dynamic code 60 to the header of the message, and transmits the resulting message and header to the district station  $A_0B_1C_1$ .

**[0062]** Transit stations such as the central and regional stations 34 and 32 individually identify the dynamic vehicle code 60 of the message and transfer it to the district station  $A_0B_1C_1$ . On reception of the message and header, the district station  $A_0B_1C_1$  identifies the roadside station 10 which is represented by the running area code 64 of the header and, based on the identified roadside station 10, references the roadside station table 134. In this example, since the roadside station code is representative of " $D_5$ ", the district station  $A_0B_1C_1$  determines that the paging group made up of the roadside stations  $D_3$ ,  $D_4$  and  $D_6$  is the group to be accessed. Then, the district station  $A_0B_1C_1$  determines the running direction of the mobile station  $A_1B_1M_{03}$  and accesses all of the roadside stations  $D_3$ ,  $D_4$  and  $D_6$  at the same time. The rest of the call termination sequence is the same as the previous embodiment.

**[0063]** As described above, in this particular embodi-

ment, the roadside stations 10 which are geometrically associated with other are arranged in a paging group configuration. To terminate a call at any of the mobile stations 16, the current position of the mobile station 16 is determined by accessing a registry station where the mobile station 16 is registered and, then, the roadside stations 10 belonging to a single group associated with or estimated from the determined current position access the desired mobile station 16 at the same time. This eliminates the problem ascribable to the uncertainty of the position of the mobile station 16 and thereby promotes efficient call termination control.

**[0064]** In the case that a single district station 30 covers a single paging group, the current position data supplied in the event of call termination does not have to include a roadside station code and, further, the district station 30 does not have to have the roadside station table 134. In this case, the district station 30 will access all of the roadside stations 10 lying in its coverage area in response to an incoming call.

**[0065]** Hereinafter will be described an alternative embodiment of the present invention in which information indicative of whether or not a mobile station 16 is running past a roadside station 10 located at the end of the coverage area of a district station 30 is supplied, so that the movement of the mobile station 16 may be estimated with accuracy to implement efficient call termination control. FIG. 12 shows a specific format of the vehicle code which is applicable to this embodiment. In the figure, the current position data associated with the mobile station 16 includes the land station code " $A_0B_1C_1$ " and a boundary bit 64a, which has to be understood as the second position information (64a) in the following indicative of whether or not a mobile station (16) is located at an outgoing end of an area, in the form of the running area code 64 of the dynamic vehicle code 60.

**[0066]** The boundary bit 64a shows whether or not the roadside station 10 detected the mobile station 16 is located at the end of the coverage area of the district station 30. As shown in FIG. 13, assume that the roadside stations  $D_0$  to  $D_7$  belonging to the district station  $A_0B_1C_1$  are arranged linearly along a single road 136 such as a thruway, and that the roadside station  $D_7$  which adjoins another district station  $A_0B_1C_2$  at the end of the coverage area of the district station  $A_0B_1C_1$  has detected the mobile station 16. Then, the district station  $A_0B_1C_1$  sets a significant bit such as a (logical) ONE in the boundary bit 64a. For this purpose, in this particular embodiment, the district station 30 has the roadside station table 134 (FIG. 11) that stores which of the roadside stations 10 belonging to its own coverage area adjoins another district station 30, i. e., which of such roadside stations 10 are the "end stations" in the limited coverage area. In the example shown in FIG. 13, the roadside station  $A_0B_1C_1D_7$  is listed in the roadside station table 134 as "outgoing end station" with respect to the running direction of the vehicle 12. While a single outgoing end station

is shown in this example, two or more outgoing end stations may exist in the case of actual roads which are developed two-dimensionally.

**[0067]** As shown in FIG. 14, which is an example of an illustrative embodiment of the present invention, when the roadside station  $A_0B_1C_1D_5$  detects the mobile station  $A_1B_1M_{03}$  (150), the district station  $A_0B_1C_1$  determines that the roadside station  $A_0B_1C_1D_5$  is not the outgoing end station by referencing the roadside station table 134 (151). In this condition, the district station  $A_0B_1C_1$  sends the running area code 64 and dynamic vehicle code 50 (154) while maintaining a (logical) ZERO in the boundary bit 64a (152). When the roadside station  $A_0B_1C_1D_7$  detects the mobile station  $A_1B_1M_{03}$ , the district station  $A_0B_1C_1$  sees that the roadside station  $A_0B_1C_1D_7$  is the outgoing end station by referencing the roadside station table 134. Then, the district station  $A_0B_1C_1$  turns the boundary bit 64a from ZERO to ONE (153) and transmits the mobile station data 50 and 60 (154).

**[0068]** Switching stations lying above the district station  $A_0B_1C_1$  such as the regional station  $A_0B_1$  and central stations  $A_0$  and  $A_1$  identify the destination of the mobile station position data on the basis of the vehicle code " $A_1B_1M_{03}$ " and repeat it to the registry station in which the mobile station  $A_1B_1M_{03}$  is registered, i. e. the regional station  $A_1B_1$  in this example. On reception of the mobile station position data, i. e., the static vehicle code 50 and dynamic vehicle code 60, the registry station  $A_1B_1$  identifies the mobile station 16 of interest, i. e., the station  $M_{03}$  in this example on the basis of the mobile station code 54 and stores such position data in the associated location of the running vehicle table 80. These position data, of course, include the boundary bit 64a.

**[0069]** Again, a reference will be made to FIG. 9 for describing a sequence available with this particular embodiment to terminate a call from the center 26 or 28 to the mobile station  $A_1B_1M_{03}$  on the basis of the mobile station position data which is constantly updated at the registry station  $A_1B_1$ . A message to be sent from the center 26 or 28 to the mobile station  $A_1B_1M_{03}$  is transmitted to the registry station  $A_1B_1$  via the central station 34, together with a header in the form of the static vehicle code 50 which includes a destination code " $A_1B_1M_{03}$ ". For so transferring the message, the transmit stations individually identifies the destination code " $A_1B_1M_{03}$ " of the message. On reception of the message with the header, the station  $A_1B_1$  checks the destination code to see if the mobile station  $A_1B_1M_{03}$  is a registered or qualified station and, if it is qualified, temporarily stores the message in a memory (not shown) (140). At this instant, the registry station  $A_1B_1$  returns a confirmation signal to the center 26 or 28, although not shown in the figure.

**[0070]** The registry station  $A_1B_1$  checks the running vehicle table 80 (160, FIG. 15) to determine the current position of the mobile station  $A_1B_1M_{03}$  of interest as indicated by the mobile station position data. If a ONE is

not set in the boundary bit 64a associated with the mobile station  $A_1B_1M_{03}$  (161), the registry station  $A_1B_1$  prepares, on the basis of the current position such as " $A_0B_1C_1$ ", a dynamic vehicle code 60 which includes the running area code in the form of the address " $A_0B_1C_1$ " of the district station 30 (162). The registry station  $A_1B_1$  reads the message out of the memory, adds the dynamic code 60 to the header, and sends the resulting header and message to the district station  $A_0B_1C_1$  (163).

**[0071]** Transit stations such as the central station 34 and regional station 32 identify the dynamic vehicle code 60 of the message and transfer it to the district station  $A_0B_1C_1$ . As the district station  $A_0B_1C_1$  receives the message together with the header, it accesses all of its associated roadside stations 10 at the same time.

**[0072]** Referring again to FIG. 15, if the boundary bit 64a is a ONE as determined in the step 161 by the registry station  $A_1B_1$ , in the illustrative embodiment, the transmission of the message is not effected until position data having a ZERO in the boundary bit 64a has been received afterwards with respect to the mobile station  $A_1B_1M_{03}$  (164). This is because, even if call termination at the mobile station  $A_1B_1M_{03}$  is attempted via the district station  $A_0B_1C_1$ , the probability that the mobile station  $A_1B_1M_{03}$  seizes it is generally small. In this manner, this embodiment allows a minimum of ineffective termination of a call at the mobile station 16 to occur by giving special significance to the outgoing end station which is present in the coverage area of the district station 30.

**[0073]** If desired, in the step 164 where the registry station  $A_1B_1$  is in a waiting condition, whether or not new position data arrives within a predetermined period of time may be determined. If the predetermined period of time expires before the arrival of new position data, the district station  $A_0B_1C_1$  stored in the running vehicle table 30 will access the mobile station  $A_1B_1M_{03}$  by paging.

**[0074]** An alternative illustrative embodiment will be described which is so constructed as to effect a paging to a mobile station which is running at the incoming end of the coverage area of an adjoining district station 30 also. One of characteristic features of this embodiment is that particular ones of the roadside stations 10 are subordinate not only to their associated district stations 30 but also to other district stations 30, as indicated by dotted lines 180 in FIG. 16. Specifically, assuming that the roadside station  $D_7$  geographically belonging to the coverage area of a certain district station  $C_1$  and accommodated in the latter is located in close proximity to the coverage area of another district station  $C_2$ , i. e., the roadside station  $D_7$  is an "end station", the roadside station  $D_7$  is also connected to the district station  $C_2$  such that it is logically subordinate to the district station  $C_2$  as to the control over call termination at the mobile station 16 and is controlled by the latter as well.

**[0075]** For example, the district station  $C_1$  accommodates the roadside stations  $D_0$  to  $D_7$  so that when any of the subordinate roadside stations  $D_0$  to  $D_7$  detects

the mobile station 16, the district station  $C_1$  is informed of the detection from that roadside station as usual. However, in response to an incoming call meant for the mobile station 16, the district station  $C_1$  simultaneously accesses not only its own roadside stations  $D_0$  to  $D_7$  but also a roadside station of the adjacent area, e. g. , a roadside station  $A_0B_1C_2D_0$  which is located at the incoming end of the adjacent district station  $C_2$ . That the call termination control extends from the district station 30 located in a certain region to a roadside station 10 located in the adjacent region is represented by the dotted lines 180 in FIG. 16. In the example shown in FIG. 16, the roadside station  $D_7$  associated with the district station  $C_1$  is also an incoming end station when it comes to the vehicle 12 which moves away from the district station  $C_2$  to the district station  $C_1$  and, therefore, it is subordinate to the district station  $C_2$  with respect to call termination control. It is to be noted that two or more incoming end stations may exist in the case of an actual road because the roadside stations 10 associated with such a road are usually developed two-dimensionally.

**[0076]** Concerning the roadside station  $D_7$  located at the end of the coverage area of the district station  $C_1$ , the land station code may include the boundary bit (FIG. 12) indicative of the fact that the coverage area terminates at the station  $D_7$  when the station  $D_7$  has detected the mobile station  $A_1B_1M_{03}$ , as in the previous embodiment. Further, an arrangement may be made such that when a certain district station 30 has detected the mobile station  $M_{03}$  for the first time via any of its subordinate roadside stations 10, it reports the detection to the registry station  $A_1B_1$  where the mobile station  $M_{03}$  is registered.

**[0077]** It rarely occurs that the mobile station  $M_{03}$  detected by the outgoing end station  $A_0B_1C_1D_7$  remains in the coverage area of the same district station  $C_1$ . Hence, as shown in FIG. 17A, if the system architecture is such that each of the end stations  $C_1D_7$  and  $C_2D_0$  is subordinate solely to its associated district station  $C_1$  or  $C_2$ , the termination of an incoming call from the district station  $C_1$  at the mobile station  $M_{03}$  which may be attempted after the outgoing end station  $C_1D_7$  has detected the mobile station  $M_{03}$  will in many cases be unsuccessful. Generally, it is only after the incoming end station  $C_2D_0$  of the adjoining district station  $C_2$  has detected the mobile station  $M_{03}$  and reported its current position to the registry station  $A_1B_1$  that a call termination is attempted via the district station  $C_2$ . Therefore, the mobile station  $M_{03}$  cannot receive a call until, at the earliest, it reaches the zone 20 of the next roadside station  $C_2D_1$ , resulting in a substantial delay in the termination of a call. In FIG. 17A, the locations where a call can be received are indicated by bold arrows 16 while the roadside stations associated with such locations are indicated by hatching.

**[0078]** In contrast, in the illustrative embodiment, the architecture is such that the incoming end station  $C_2D_0$  of the district station  $C_2$  which adjoins the district station

$C_1$  is logically subordinate to the district station  $C_1$  as well, as shown in FIG. 17B. In this construction, even when the mobile station  $M_{03}$  enters the coverage area of the district station  $C_2$  after the outgoing end station  $C_1D_7$  of the district station  $C_1$  has detected it, the probability of a call being successfully terminated at the mobile station  $M_{03}$  is great because the district station  $C_1$  accesses not only its coverage area but also the incoming end station  $C_2D_0$  of the adjoining district at the same time.

**[0079]** In the example shown in FIG. 17, incoming and outgoing end stations 10 are shown as being subordinate with respect to opposite directions of travel of a vehicle, i. e., the end station  $C_1D_7$  of the district station  $C_1$  which adjoins the district station  $C_2$  is subordinate to the district station  $C_2$  also. This allows even the mobile station 16 running in the opposite direction from the district station  $C_2$  to the district station  $C_1$  to receive a call efficiently. However, such a both-direction double-subordinate scheme is not essential. For example, when the distance between two nearby roadside stations 10 is relatively short, the end station 10 may be subordinate to the two nearby district stations  $C_1$  and  $C_2$  with respect to one direction only, as shown in FIG. 17C. In the example shown in FIG. 17C, since the distance between the roadside stations  $C_1D_6$  and  $C_1D_7$  belonging to the district station  $C_1$  is shorter than the distance between the others, an arrangement is made such that the station  $C_1D_7$  is subordinate solely to the district station  $C_1$  as to a mobile station running in the opposite direction to the mobile station  $M_{03}$  such as  $M_{04}$ . Although the arrangement shown in FIG. 17 allows the mobile station  $M_{04}$  to receive a call only when the latter enters the service zone of the roadside station  $C_1D_6$ , the distance between the roadside station  $C_1D_6$  and the incoming end station  $C_1D_7$  is sufficiently short to prevent the serviceability from being critically degraded.

**[0080]** In this particular embodiment, when the district station 30 accesses its own roadside stations 10 at the same time for the termination of a call at the mobile station 16, it necessarily accesses the incoming end station 10 of the adjoining district also. It is not necessary, however, that the roadside station 10 of the adjoining district station be accessed as stated. For example, in the case that the current position of the motor vehicle 16 is detected with a boundary included in the running area code 64 as discussed earlier, the call termination control may be such that the incoming end station 10 of the adjoining district is accessed by paging only when the boundary bit shows that the mobile station 10 has been detected by the end station 10.

**[0081]** In summary, in this particular embodiment, a call is terminated at the mobile station by causing the district station 30 to access not only its own roadside stations 10 but also the incoming end station 10 of the adjoining district station 30 at the same time. This reduces the chance of ineffective paging for call termination and thereby enhances efficient call termination con-

trol.

**[0082]** An alternative illustrative embodiment will be described which is constructed such that, when a mobile station 16 leaves a certain district station 30, an area which the mobile station 16 will enter next is estimated to cause a district station 30 covering that area to terminate an incoming call. A specific system construction of this embodiment is shown in Fig. 18, while the hierarchy of the telecommunications network 22 is shown in FIG. 19. In the example shown in FIG. 13, the mobile station  $A_1B_1M_{03}$  running on the road 136 away from the end station  $A_0B_1C_1D_7$  will soon enter the coverage area of the adjoining district station  $A_0B_1C_2$ . In another example shown in FIG. 21, the mobile station  $A_1B_1M_{03}$  running on the road 136 away the end station 10 of the district station  $A_0B_1C_1$  will soon reach either one of district stations  $A_0B_1C_2$  and  $A_1B_0C_0$ .

**[0083]** In this particular embodiment, such a possibility of travel of the mobile station 16 over adjoining district stations 30 is stored in the form of a district station table 138 of the present invention (FIG. 18) in the memory of the registry station, e. g. the regional station  $A_1B_1$ . More specifically, the district station table of the registry station  $A_1B_1$ , for example, lists for each of the district stations 30 which belong to the network 22 the adjoining district stations 30 to which the mobile station 16 moving away from the coverage area of the district station 30 is likely to enter next. To terminate a call to the mobile station, the district station table 138 (FIG. 19) is referenced so that any adjoining district station 30 to which the mobile station 16 is likely to move is selected, as described in detail later.

**[0084]** In this embodiment, the information indicative of the current position of the mobile station 16 is implemented as the own station position information. The position information includes the land station code " $A_0B_1C_1$ " and boundary bit (FIG. 12) in the form of the running area code 64 of the dynamic vehicle code 60.

**[0085]** A sequence for terminating a call from the center 26 or 28 at the mobile station  $A_1B_1M_{03}$  by using the mobile station position data which is constantly updated by the registry station  $A_1B_1$  will be described with reference to FIG. 9, as in the previous illustrative embodiments. A message from the center 26 or 28 and meant for the mobile station  $A_1B_1M_{03}$  is sent to the registry station  $A_1B_1$  via the central station 34 together with a header in the form of the static vehicle code 50 which includes a destination code " $A_1B_1M_{03}$ ". This message transfer is effected by causing each transmit station to identify the destination code " $A_1B_1M_{03}$ " of the message. On reception of the message together with the header, the registry station  $A_1B_1$  checks the mobile station  $A_1B_1M_{03}$  as to qualification on the basis of the destination code and, if it is qualified, temporarily stores the message in its memory (not shown) (140). In this instance, the registry station  $A_1B_1$  returns a confirmation signal to the center 26 or 28.

**[0086]** By referencing the running vehicle table 80

(220, FIG. 20), the registry station  $A_1B_1$  determines the current position of the mobile station  $A_1B_1M_{03}$  on the basis of the listed position data. If a ONE which is a significant bit is not set in the boundary bit 64a (FIG. 12) of the mobile station  $A_1B_1M_{03}$  (222), the registry station  $A_1B_1$  produces a dynamic vehicle code 60 which includes a running area code 64 from the current position of the mobile station  $A_1B_1M_{03}$ , e. g. a running area code " $A_0B_1C_1$ " from the current position " $A_0B_1C_1$ ". Then, the registry station  $A_1B_1$  reads the message out of the memory, adds the dynamic code 60 to the header of the message, and sends the resulting header and message to the district station  $A_0B_1C_1$  (226). In response, the district station accesses all of its subordinate road stations 10 simultaneously.

**[0087]** Turning back to FIG. 20, if the boundary bit 64a is a ONE as determined in the step 161 by the registry station  $A_1B_1$ , the station  $A_1B_1$  references the district station table with respect to the district station code " $A_0B_1C_1$ " and thereby produces a district station which governs the district which the mobile station 16 is expected to enter next (228). In the example of the present invention shown in FIG. 13, the mobile station  $A_1B_1M_{03}$  running on the road 136 away from the end station  $A_0B_1C_1D_7$  will enter the coverage area of the district station  $A_0B_1C_2$  in due course. In this case, the registry station  $A_1B_1$  produces the district station  $A_0B_1C_2$  out of the table 138. On the other hand, in the example of the present invention of FIG. 21, the mobile station  $A_1B_1M_{03}$  running on the road 136 away from the district station  $A_0B_0C_1$  will soon reach either one of the district stations  $A_0B_1C_2$  and  $A_1B_0C_0$ . Then, the registry station  $A_1B_1$  produces the district station  $A_0B_1C_2$  and  $A_1B_0C_0$ .

**[0088]** By using the produced district station code for an address (230), the station  $A_1B_1$  transmits a message and terminate a call in the previously described manner (226). When a plurality of district addresses are produced as stated above, the station  $A_1B_1$  accesses all of them at the same time or, alternatively, one after another according to a predetermined priority order. The priority order may be set beforehand on a district station basis or may be selected randomly.

**[0089]** The estimation of a district station discussed above is effective in reducing the possibility that when a call termination at the mobile station  $A_1B_1M_{03}$  is attempted via the district station  $A_0B_1C_1$  which is indicated by the current position information, the mobile station fails to seize the call, whereby the frequency of retry is lowered. Thus, this embodiment allows a minimum of wasteful termination of a call at the mobile station 16 to occur by giving special significance to the end stations subordinate to each district station 30.

**[0090]** While adjoining district stations 30 have been shown and described as being searched by the registry station, this kind of search is not necessary and, of course, may be assigned to a station other than the registry station. For example, either the central station 34 or the regional station 32 may be provided with a similar

district station table so as to perform the search in response to a message which is destined to the mobile station 16. Further, the search of adjoining districts may be assigned to the regional stations in place of the district stations.

**[0091]** An alternative approach for the detection of the travelling position of the mobile station 16 in accordance with the present invention will be described. In this embodiment, as shown in FIG. 3, an ID code designating a mobile station 16, i. e., a vehicle specific code is constituted by a static code 50 and a dynamic code 60. As shown in FIGS. 22 and 23, the memory of each district station 30 stores a passing vehicle table 170. This table 170 lists data associated with the mobile stations 16 which are detected in the service zones 20 of all of the roadside stations that are accommodated in the district station 30. In the illustrative embodiment, it is only when the district station 30 has found a new or strange mobile station 16 in its coverage area that it holds a communication with the registry station where that mobile station 16 is registered for informing the latter of the current position of the mobile station 16. This alleviates the communication traffic needed for reporting the current position and simplifies the processing which the registry station has to execute for managing the running positions. The passing vehicle table 170 is referenced in order to determine whether or not a mobile station 16 seized by any roadside station 10 is a newcomer in the coverage area of the district station 30. Also, when the roadside stations 10 are not arranged in a paging group configuration as to an incoming call, the table 170 is used to search for a roadside station 10 which can terminate a call at the mobile station 16.

**[0092]** For example, as shown in FIG. 22, assume that one  $C_1$  of multiple district stations subordinate to a regional station  $A_0B_1$  accommodates eight roadside stations 10 which are designated respectively by station codes  $D_0$  to  $D_7$ . In the figure, the sixth roadside station 10 as counted from the left is designated by a station code " $A_0B_1C_1D_5$ ". When a mobile station 16 having a static vehicle code 50 of " $A_1B_1M_{03}$ " is polled by the roadside station  $A_0B_1C_1D_5$  while running within the zone 20 of the latter, it returns an ID code " $A_1B_1M_{03}$ " to the roadside station as a land station code 52 and a mobile station code 54.

**[0093]** The roadside station 10 may store in the passing vehicle table 82 the data which are associated with the subscriber vehicles 12 and obtained from the mobile stations 16 present in the zone 20 at each polling period. The roadside station 10 transfers such data to the associated district station 30 over the channel 36. In this embodiment, the district station 30 is so constructed as to inform the registry station  $A_1B_1$  of the current position of a particular mobile station such as  $A_1B_1M_{03}$  for the first time when it has detected the mobile station through any of its associated roadside stations 10

**[0094]** As shown in FIG. 13, assume that the mobile station  $A_1B_1M_{03}$  running on the road 136 has moved

away from the end roadside station  $A_0B_1C_1D_7$  subordinate to the district station  $A_0B_1C_1$  into the zone 20 which is defined by the first roadside station  $A_0B_1C_2D_0$  subordinate to an adjoining district station  $A_0B_1C_2$ . Then, the roadside station  $A_0B_1C_2D_0$  reports the vehicle code 50 of the mobile station  $A_1B_1M_{03}$  to its associated district station  $A_0B_1C_2$  which in turn stores it in its passing vehicle table 170. At this instant, the district station  $A_0B_1C_2$  checks the table 170 to see if the vehicle code " $A_1B_1M_{03}$ " has been listed in the past (172, FIG. 24). If it has not been listed, the district station  $A_0B_1C_2$  transfers the current position data of the mobile station  $A_1B_1M_{03}$  to the registry station  $A_1B_1$  via its associated district station  $A_0B_1$ . In this case, the station code " $A_0B_1C_2$ " sufficiently implements the current position data.

**[0095]** More specifically, as shown in FIG. 23, each district station 30 has a station code generating unit 132 for generating a land station code 52 which designates the station 30 itself. Concerning the district station  $A_0B_1C_2$ , for example, the station code generating unit 132 is loaded with a code " $A_0B_1C_2$ " as the land station code 52. The vehicle code " $A_1B_1M_{03}$ " of the mobile station 16 received by the roadside station  $A_0B_1C_2D_0$  is once stored in the passing vehicle table 82 of the roadside station 10 while being transferred to the associated district station  $A_0B_1C_2$ .

**[0096]** As the district station  $A_0B_1C_2$  decides that the vehicle code " $A_1B_1M_{03}$ " has not been stored in the passing vehicle table 170 (172), it determines that the mobile station  $A_1B_1M_{03}$  is registered in the regional station  $A_1B_1$  which belongs to the central station  $A_1$  on the basis of the vehicle code " $A_1B_1M_{03}$ " and, then, transfers the vehicle code " $A_1B_1M_{03}$ " to the station  $A_1B_1$ , as shown in FIG. 24. At this instant, the district station  $A_0B_1C_2$  sends its own position information for indicating the current position of the mobile station 16. This position information includes the land station code " $A_0B_1C_2$ " in the form of the running area code 64 of the dynamic vehicle code 60.

**[0097]** Switching stations lying above the district station  $A_0B_1C_2$  such as the regional station  $A_0B_1$  and central stations  $A_0$  and  $A_1$  individually repeat the mobile station position data toward the registry station, i. e., the regional station  $A_1B_1$  in this example while identifying the destination on the basis of the vehicle code " $A_1B_1M_{03}$ ". On receiving the mobile station position, i. e., the static vehicle code 50 and dynamic vehicle code 60, the registry station  $A_1B_1$  identifies the mobile station 16 of interest, i. e., the mobile station  $M_{03}$  in this example on the basis of the mobile station code 54 and writes these position data in a predetermined location of the running vehicle table 80. In this manner, the running vehicle table 80 of the registry station  $A_1B_1$  is constantly updated by incoming new data. In this system, a communication for reporting the current position occurs only when a new mobile station 16 is found in the coverage area of the district station 30, so that the communication

traffic is alleviated and the processing to be executed by the registry station for dealing with the running positions is simplified.

[0098] The current position data associated with each mobile station 16 is constantly updated. Concerning the mobile station  $M_{03}$ , for example, when any of the district stations 30 detects it through its subordinate roadside station 10 for the first time, the district station 30 informs the registry station  $A_1B_1$  of the presence of the mobile station  $M_{03}$ . Hence, the data listed in the running vehicle table 80 is updated as to the mobile station  $M_{03}$ .

[0099] It is to be noted that a particular mobile station 16 is not always detected for the first time through a roadside station 10 which is located at the end of the coverage area of a district station 30. Specifically, it may occur that the district station 30 finds the mobile station 16 for the first time through its subordinate roadside station 10 other than the end station 10, e. g., when the vehicle 12 moves into the coverage area of another district station 30 with the power supply of the on-board unit 16 being turned off and then the power supply is turned on.

[0100] To summarize this embodiment, each mobile station 16 is registered in a particular land station beforehand. When a district station 30 detects a particular mobile station 16 for the first time through any of its subordinate roadside stations 10, it informs the registry station of the current position of the mobile station 16. The registry station in turn holds the current position data and constantly updates it on a real time basis. Since it is only when the district station 30 has detected the mobile station 16 through the subordinate roadside station 10 that it reports the current position of the mobile station 16 to the registry station, the communication traffic for reporting the current position is minimized and therefore prevented from interfering with the data communication traffic which is the primary traffic.

## Claims

### 1. A mobile telecommunications system comprising:

- a mobile station (16);
- a plurality of base stations (10) each communicable with said mobile station (16) over a radio link, said plurality of base stations (10) having service zones (20) that are spaced apart from each other by an area in which the mobile station is substantially not responsive to an electromagnetic wave on the radio link, and being allowed to share a single frequency of the electromagnetic wave; and
- a communication network (22) interconnected to said plurality of base stations (10) and constituted by a plurality of switching stations (30, 32, 34) for switching a call to and from said plurality of base stations (10) in accordance with

an identification code designating said mobile station (16) and position information of said mobile station (16), wherein

in a first one of said plurality of switching stations (30, 32, 34), said mobile station (16) is registered in association with the identification code,

said switching stations (30, 32, 34) being arranged to receive the identification code from said mobile station (16), to add information associated with a position of said mobile station (16) to said identification code to form the position information of said mobile station (16) and to transfer the position information to said first switching station,

said first switching station being arranged to store the position information in association with the identification code to update the stored position information,

### characterized in that

said communication network (22) comprises a table (138) defining how each of said plurality of switching stations (30) is adjacent to ones of said plurality of switching stations (30), with reference to their coverage areas,

associated ones of said plurality of base stations (10) with respect to an area form a group and are interconnected to a second one of said plurality of switching stations (30),

the position information comprises first position information (64) representative of a position of said mobile station (16) and second position information (64a) indicative of whether or not said mobile station (16) is located at an outgoing end of the coverage area of a switching station,

each of said plurality of switching stations (30, 32, 34) is arranged to transfer, when one of said plurality of base stations (10) to which the switching station is interconnected detects said mobile station (16), the first position information (64) and the second position information (64a) to said first switching station (30, 32, 34);

said first switching station is adapted to reference, when an incoming call is to be terminated at said mobile station (16), the first and second position information (64, 64a), and to cause, if the second position information (64a) shows that said mobile station (16) is not located at the outgoing end of the coverage area, the call to be terminated at said mobile station (16) from said switching station (30) associated with the first position information (64), and to reference, if the second position information (64a) shows that said mobile station (16) is located at the outgoing end of the coverage area, the table (138) to produce an indication of ones of said switching stations (30) which are adjacent to said switching station (30) associated with the first

position information (64), make an access to the switching stations (30) thus indicated and cause the call to be terminated at said mobile station (16) via one of the switching stations (30) thus indicated.

## Patentansprüche

1. System für die mobile Telekommunikation, das umfaßt:

eine Mobilstation (16);  
mehrere Basisstationen (10), die jeweils mit der Mobilstation (16) über eine Funkverbindung kommunizieren können, wobei die mehreren Basisstationen (10) Dienstzonen (20) besitzen, die voneinander durch einen Bereich beabstandet sind, in dem die Mobilstation im wesentlichen nicht auf eine elektromagnetische Welle auf der Funkverbindung antwortet, und die eine einzige Frequenz der elektromagnetischen Welle gemeinsam nutzen dürfen; und ein Kommunikationsnetz (22), das mit den mehreren Basisstationen (10) verbunden und durch mehrere Vermittlungsstationen (30, 32, 34) gebildet ist, die einen Anruf an die bzw. von den mehreren Basisstationen (10) entsprechend einem Identifizierungscode, der die Mobilstation (16) bezeichnet, und entsprechend Positionsinformationen der Mobilstation (16) vermitteln, wobei in einer ersten der mehreren Vermittlungsstationen (30, 32, 34) die Mobilstation (16) in Zuordnung zu dem Identifizierungscode registriert ist, die Vermittlungsstationen (30, 32, 34) so beschaffen sind, daß sie den Identifizierungscode von der Mobilstation (16) empfangen, um einer Position der Mobilstation (16) zugeordnete Informationen zu dem Identifizierungscode hinzuzufügen, um die Positionsinformationen der Mobilstation (16) zu bilden und sie an die erste Vermittlungsstation zu übertragen, die erste Vermittlungsstation so beschaffen ist, daß sie die Positionsinformationen in Zuordnung zu dem Identifizierungscode speichert, um die gespeicherten Positionsinformationen zu aktualisieren,

**dadurch gekennzeichnet, daß**

das Kommunikationsnetz (22) eine Tabelle (138) umfaßt, die unter Bezugnahme auf die Abdeckungsbereiche jeder der mehreren Vermittlungsstationen (30) definiert, wie jede dieser mehreren Vermittlungsstationen (30) an einige der mehreren Vermittlungsstationen (30) angrenzt,

einige der mehreren Basisstationen (10), die einander in bezug auf einen Bereich zugeordnet

sind, eine Gruppe bilden und mit einer zweiten der mehreren Vermittlungsstationen (30) verbunden sind,

die Positionsinformationen erste Positionsinformationen (64), die eine Position der Mobilstation (16) repräsentieren, und zweite Positionsinformationen (64a), die angeben, ob sich die Mobilstation (16) an einem Ausgangsende des Abdeckungsereichs einer Vermittlungsstation befindet, umfassen,

jede der mehreren Vermittlungsstationen (30, 32, 34) so beschaffen ist, daß sie dann, wenn eine der mehreren Basisstationen (10), mit der die Vermittlungsstation verbunden ist, die Mobilstation (16) erfaßt, die ersten Positionsinformationen (64) und die zweiten Positionsinformationen (64a) an die erste Vermittlungsstation (30, 32, 34) überträgt,

die erste Vermittlungsstation so beschaffen ist, daß sie dann, wenn ein ankommender Anruf an die Mobilstation (16) gerichtet ist, auf die ersten und zweiten Positionsinformationen (64, 64a) Bezug nimmt und dann, wenn die zweiten Positionsinformationen (64a) zeigen, daß sich die Mobilstation (16) nicht am Ausgangsende des Abdeckungsbereichs befindet, veranlassen, daß der Anruf von der Vermittlungsstation (30), der die ersten Positionsinformationen (64) zugeordnet sind, an die Mobilstation (16) gerichtet wird, und dann, wenn die zweiten Positionsinformationen (64a) zeigen, daß sich die Mobilstation (16) am Ausgangsende des Abdeckungsbereichs befindet, auf die Tabelle (138) Bezug nimmt, um einen Hinweis auf diejenigen der Vermittlungsstationen (30) zu erzeugen, die an die Vermittlungsstation (30) angrenzen, der die ersten Positionsinformationen (64) zugeordnet sind, einen Zugriff auf die somit angegebenen Vermittlungsstationen (30) vornimmt und veranlaßt, daß der Anruf über eine der somit angegebenen Vermittlungsstationen (30) an die Mobilstation (16) gerichtet wird.

## Revendications

1. Système de télécommunications mobiles, comprenant :

une station mobile (16);  
une pluralité de stations de base (10) pouvant chacune communiquer avec ladite station mobile (16) par l'intermédiaire d'une liaison radio, ladite pluralité de stations de base (10) ayant des zones de desserte (20) qui sont mutuellement espacées par un domaine dans lequel la station mobile n'est pratiquement pas sensible à une onde électromagnétique sur la liaison radio, et étant autorisées à partager une fréquence unique de l'onde électromagnétique; et un réseau de communication (22) interconnec-

té à ladite pluralité de stations de base (10) et  
 constitué d'une pluralité de stations de commu-  
 tation (30, 32, 34) pour commuter un appel vers  
 et en provenance de ladite pluralité de stations  
 de base (10) en conformité avec un code 5  
 d'identification désignant ladite station mobile  
 (16) et avec des informations de position de la-  
 dite station mobile (16), dans lequel  
 dans une première de ladite pluralité de sta-  
 tions de commutation (30, 32, 34), ladite station 10  
 mobile (16) est enregistrée en association avec  
 le code d'identification,  
 lesdites stations de commutation (30, 32, 34)  
 étant aptes à recevoir le code d'identification de  
 ladite station mobile (16), à ajouter des infor- 15  
 mations associées à une position de ladite sta-  
 tion mobile (16) audit code d'identification pour  
 former les informations de position de ladite  
 station mobile (16) et transférer les informa-  
 tions de position à ladite première station de 20  
 commutation ;  
 ladite première station de commutation étant  
 apte à stocker les informations de position en  
 association avec le code d'identification pour  
 mettre à jour les informations de position stoc- 25  
 kées,

#### caractérisé en ce que

ledit réseau de communication (22) com-  
 prend une table (138) définissant la façon dont cha- 30  
 cune de ladite pluralité de stations de commutation  
 (30) est adjacente à certaines de ladite pluralité de  
 stations de commutation (30) en référence à leurs  
 domaines de couverture,

celles qui sont associées de ladite pluralité de 35  
 stations de base (10) vis-à-vis d'un domaine for-  
 ment un groupe et sont interconnectées à une se-  
 conde de ladite pluralité de stations de commuta-  
 tion (30),

les informations de position comprennent une 40  
 première information de position (64) représenta-  
 tive d'une position de ladite station mobile (16) et une  
 seconde information de position (64a) indiquant si  
 oui ou non ladite station mobile (16) se trouve à une 45  
 extrémité sortante du domaine de couverture d'une  
 station de commutation,

chacune de ladite pluralité de stations de  
 commutation (30, 32, 34) est apte à transférer, lors-  
 que l'une de ladite pluralité de stations de base (10)  
 à laquelle la station de commutation est intercon- 50  
 nectée détecte ladite station mobile (16), la premiè-  
 re information de position (64) et la seconde infor-  
 mation de position (64a) à ladite première station  
 de commutation (30, 32, 34) ;

ladite première station de commutation est 55  
 apte à faire référence, lorsqu'un appel entrant doit  
 être interrompu au niveau de ladite station mobile  
 (16), aux première et seconde informations de po-

sition (64, 64a), et à faire en sorte que si la seconde  
 information de position (64a) montre que ladite sta-  
 tion mobile (16) ne se trouve pas à l'extrémité sor-  
 tante du domaine de couverture, l'appel soit inter-  
 rompu par ladite station mobile (16) en provenance  
 de ladite station de commutation (30) associée à la  
 première information de position (64), et à faire ré-  
 fférence, si la seconde information de position (64a)  
 montre que ladite station mobile (16) se situe à l'ex-  
 trémité sortante du domaine de couverture, à la ta-  
 ble (138) afin de produire une indication de celles  
 desdites stations mobiles (30) qui sont adjacentes  
 à ladite station de commutation (30) associée à la  
 première information de position (64), à effectuer  
 un accès aux stations de commutation (30) ainsi in-  
 diquées et à faire en sorte que l'appel soit interrom-  
 pu à ladite station mobile (16), par l'intermédiaire  
 de l'une des stations de commutation (30) ainsi in-  
 diquées.

Fig. 1

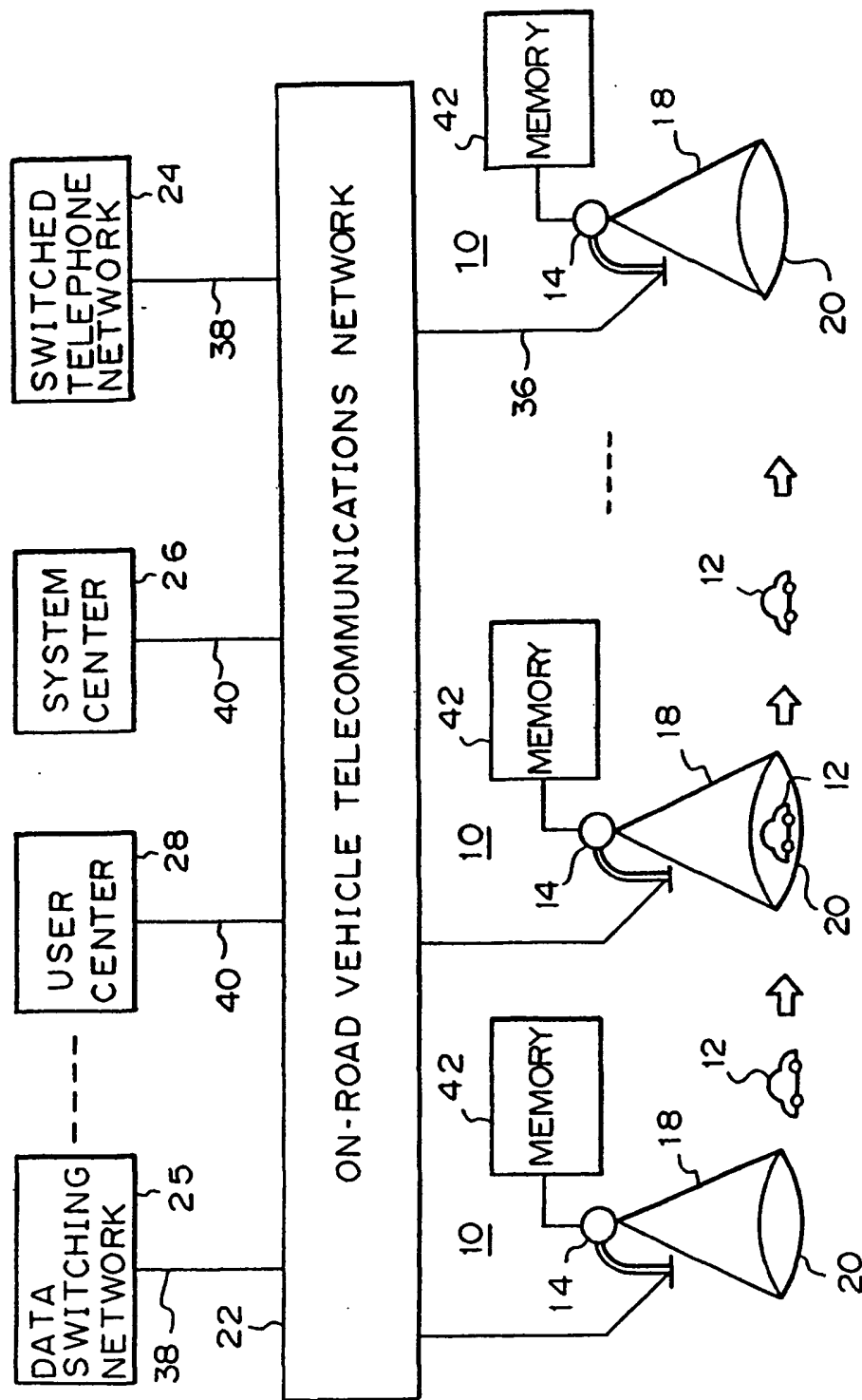


Fig. 2

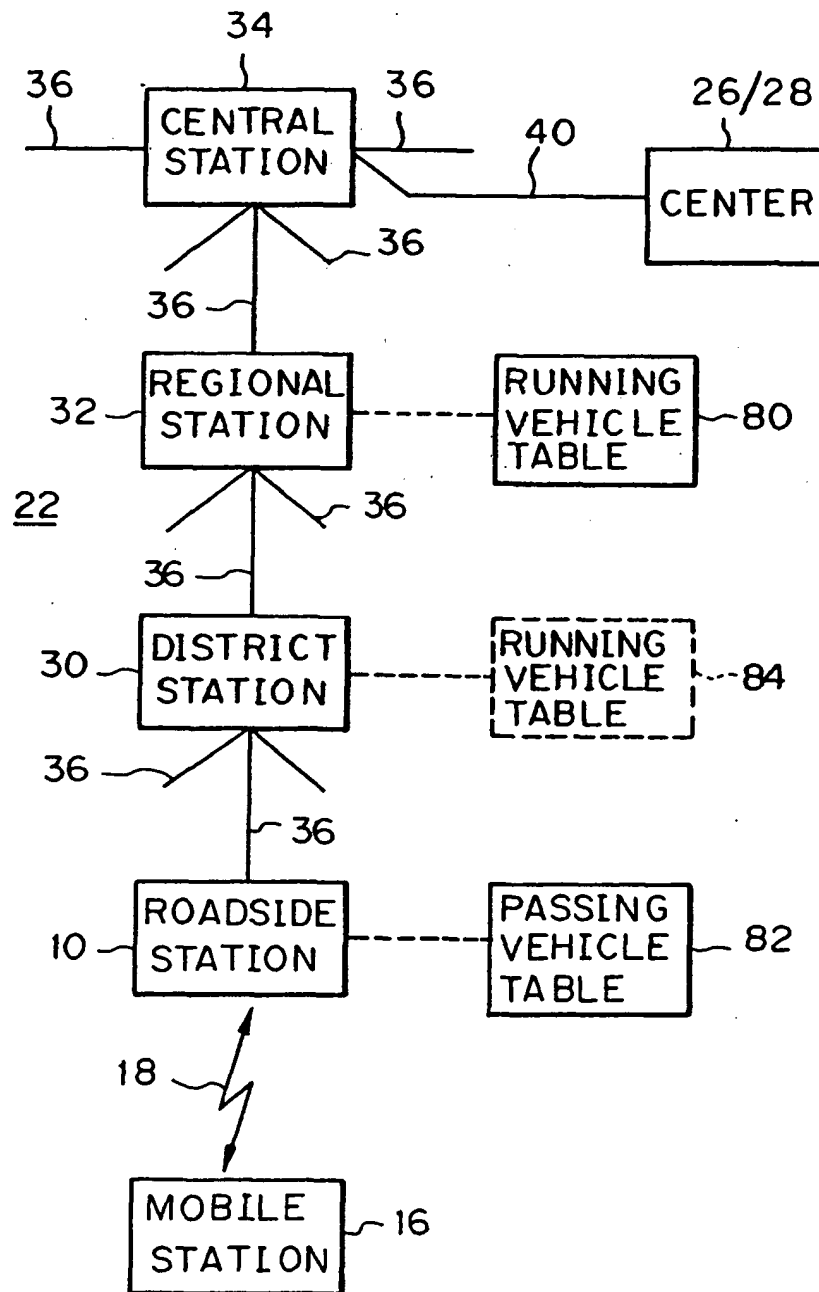


Fig. 3

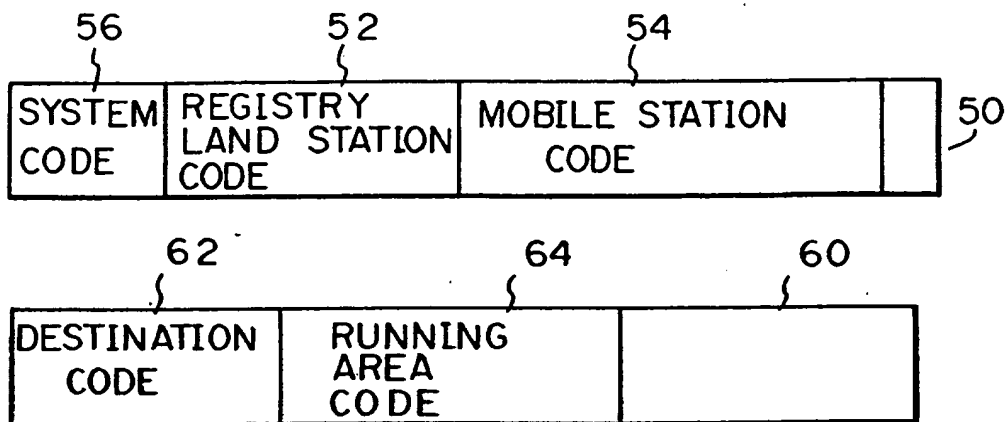


Fig. 4

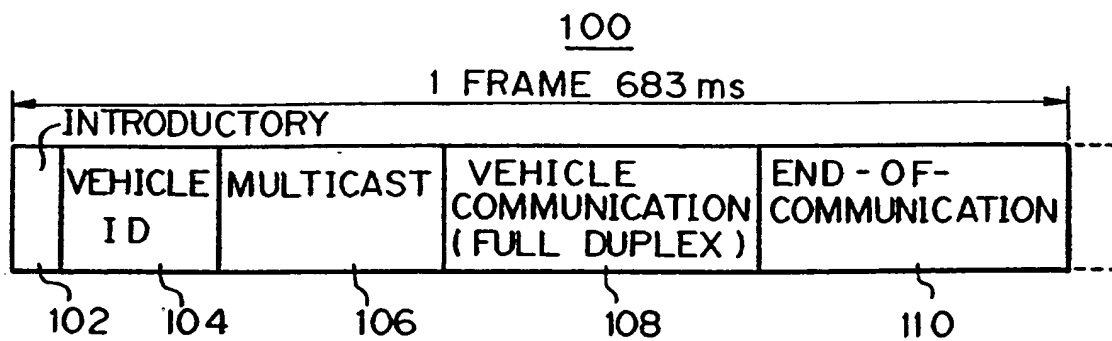


Fig. 12

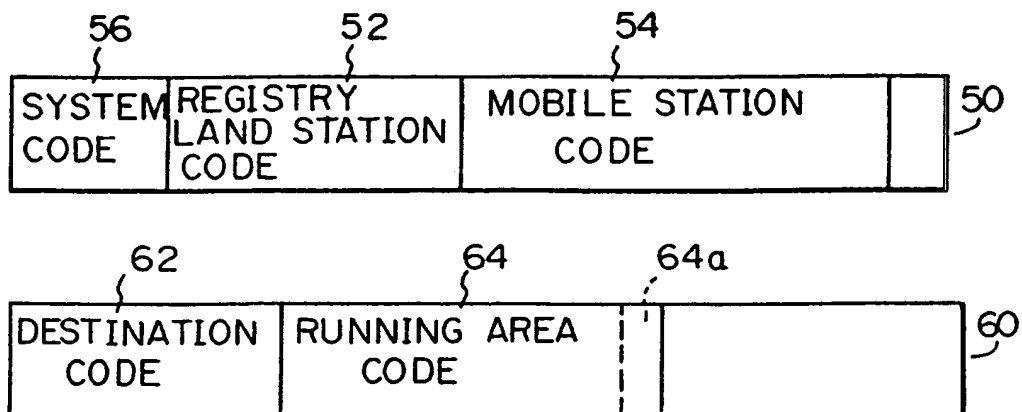


Fig. 5

MOBILE  
STATION 16

ROADSIDE  
STATION 10

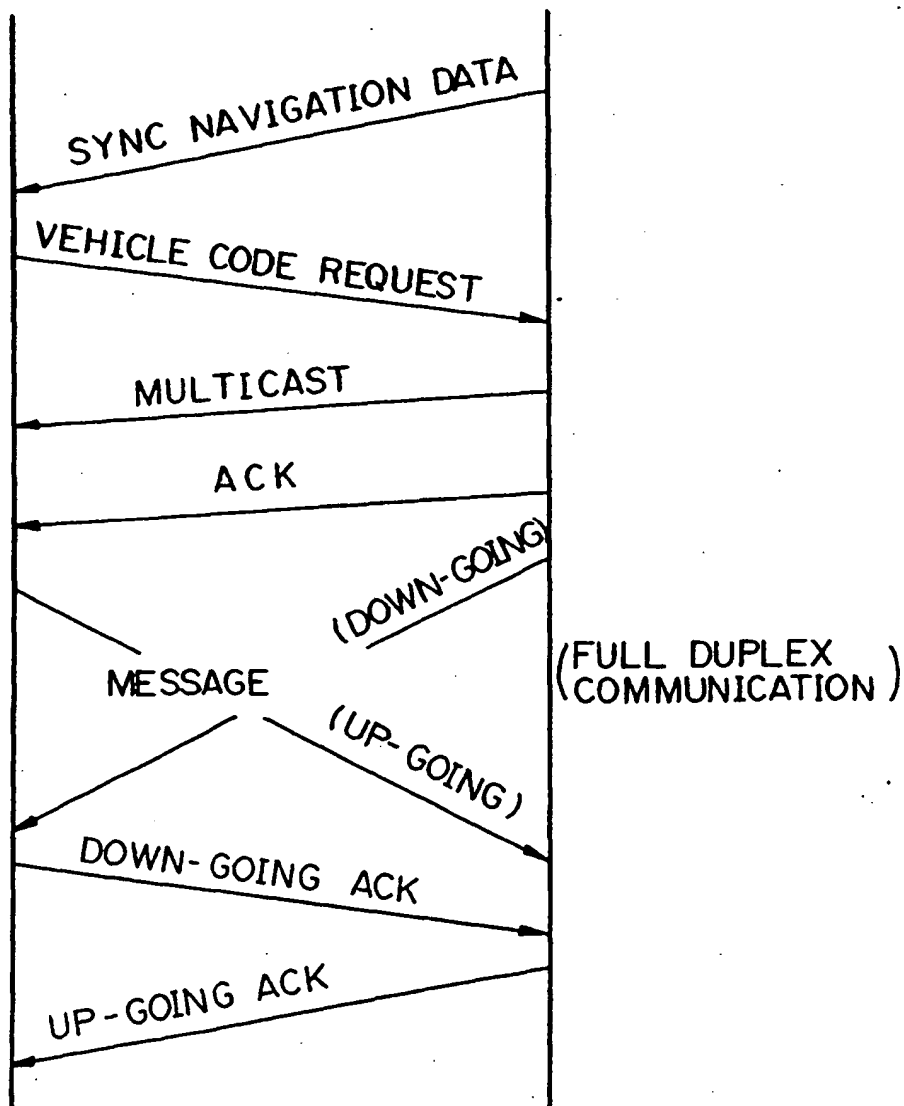


Fig. 6

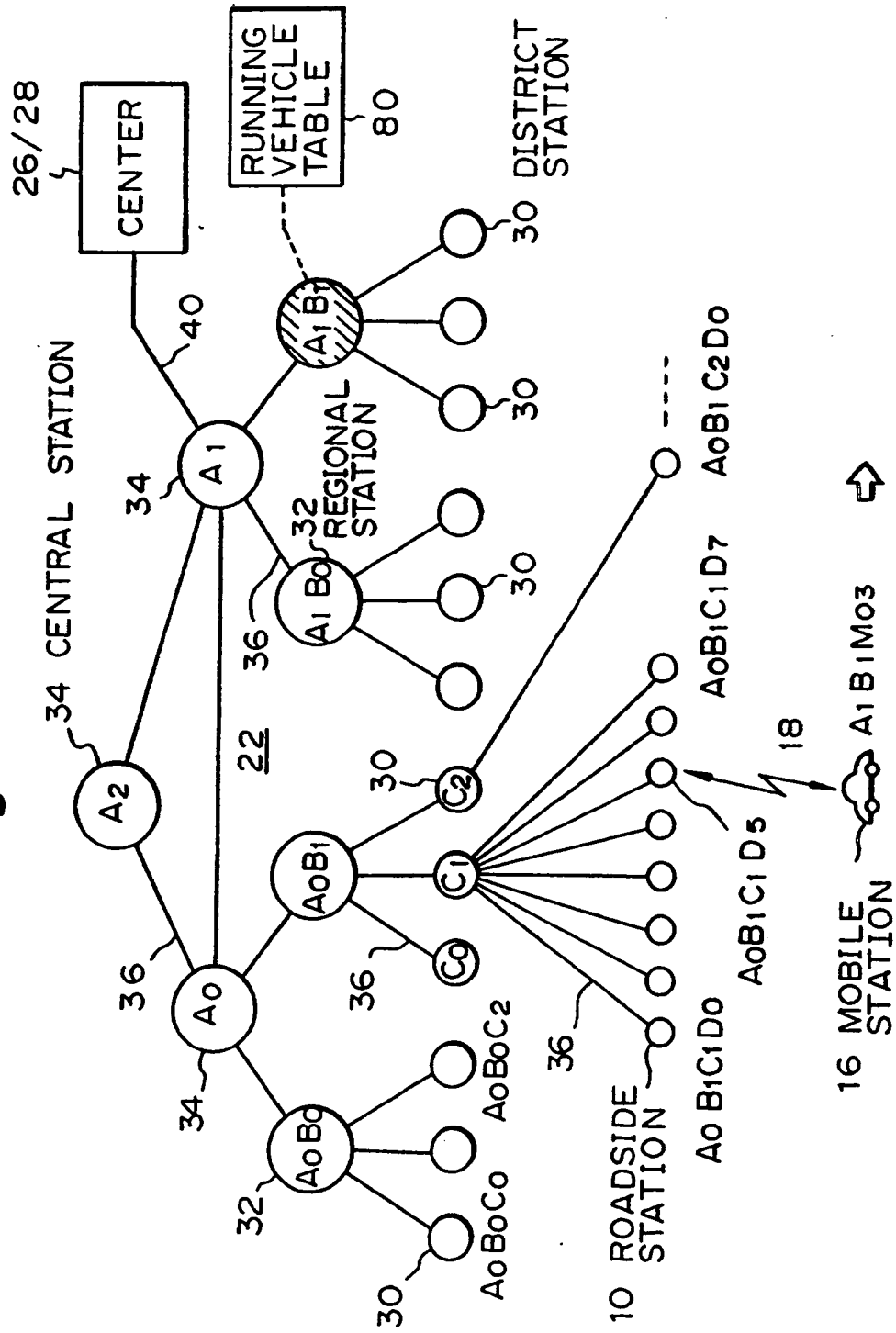


Fig. 7

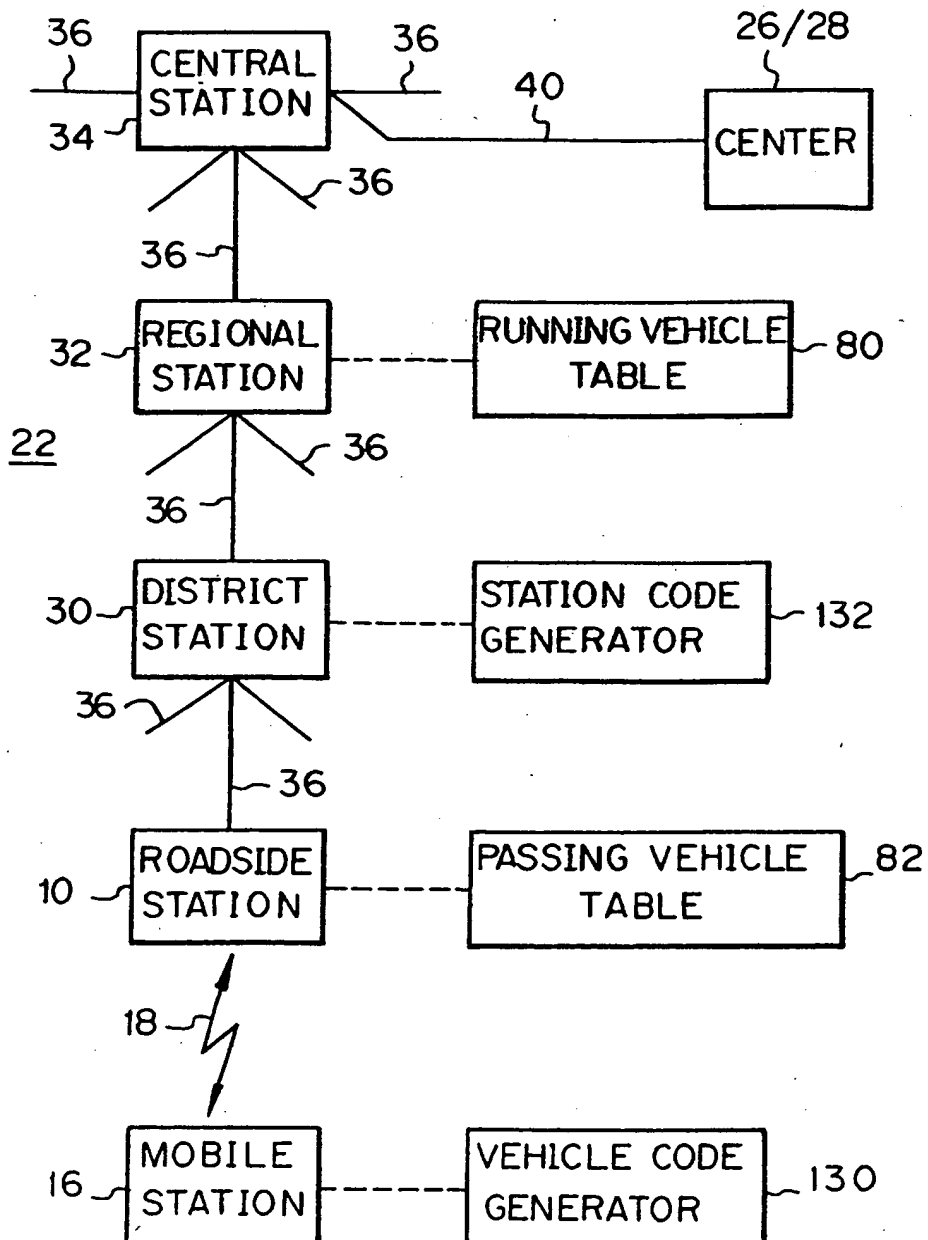


Fig. 8

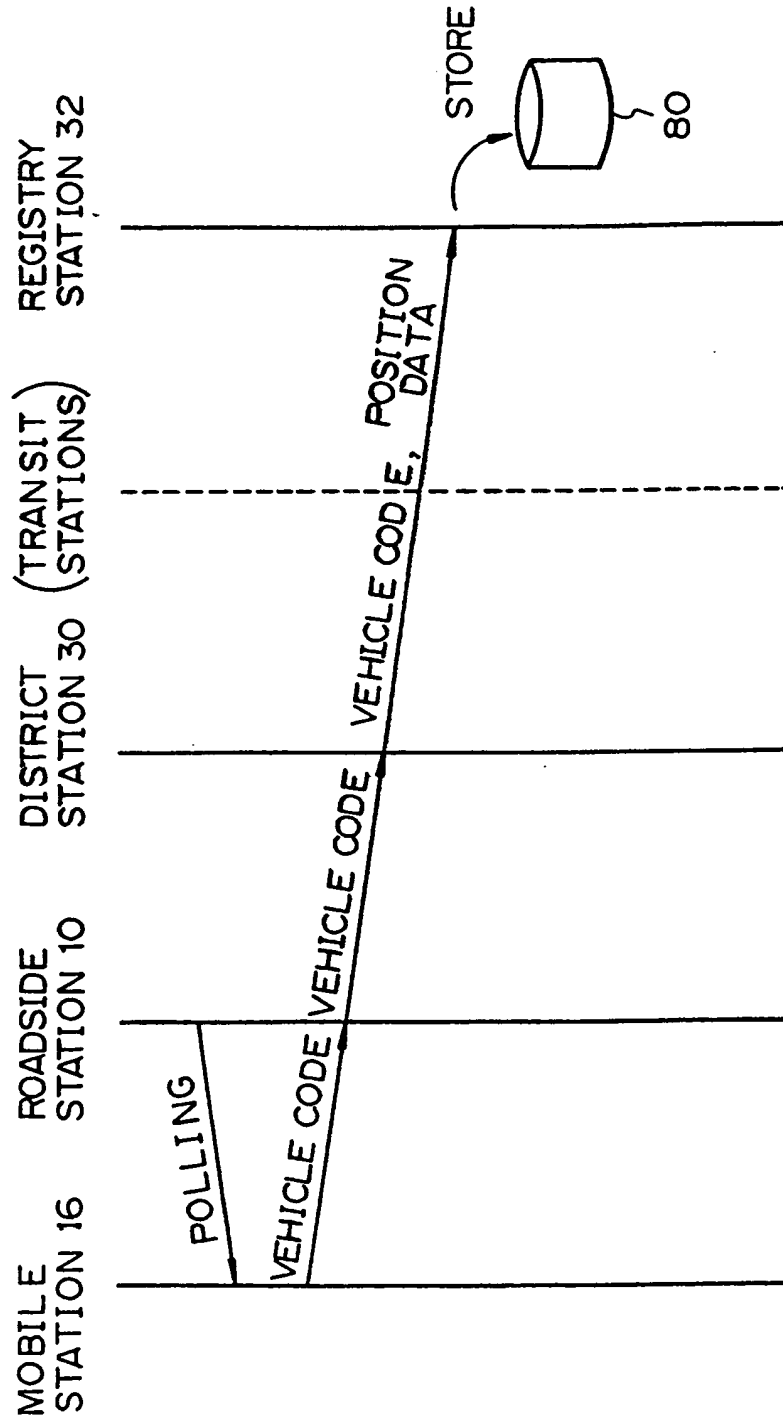


Fig. 9

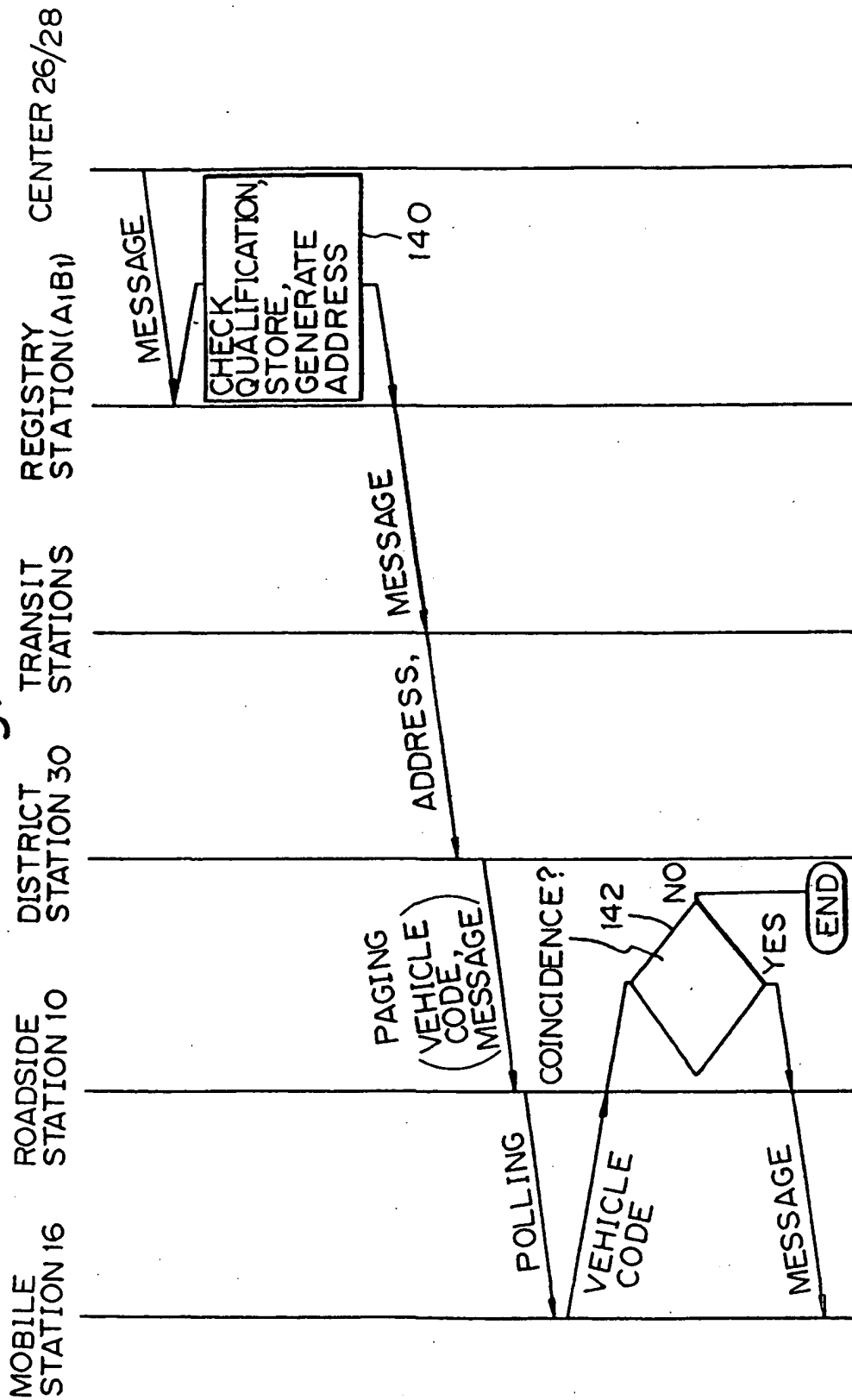


Fig. 10

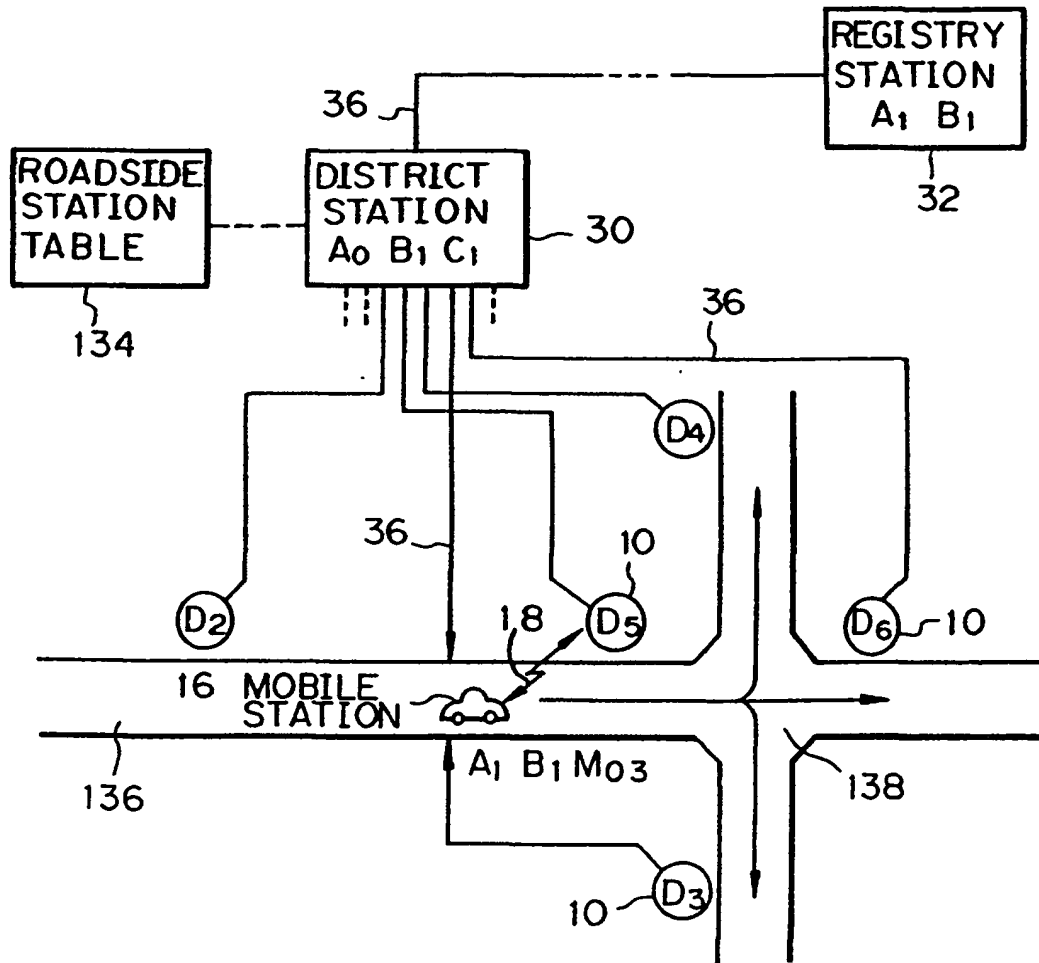


Fig. 11

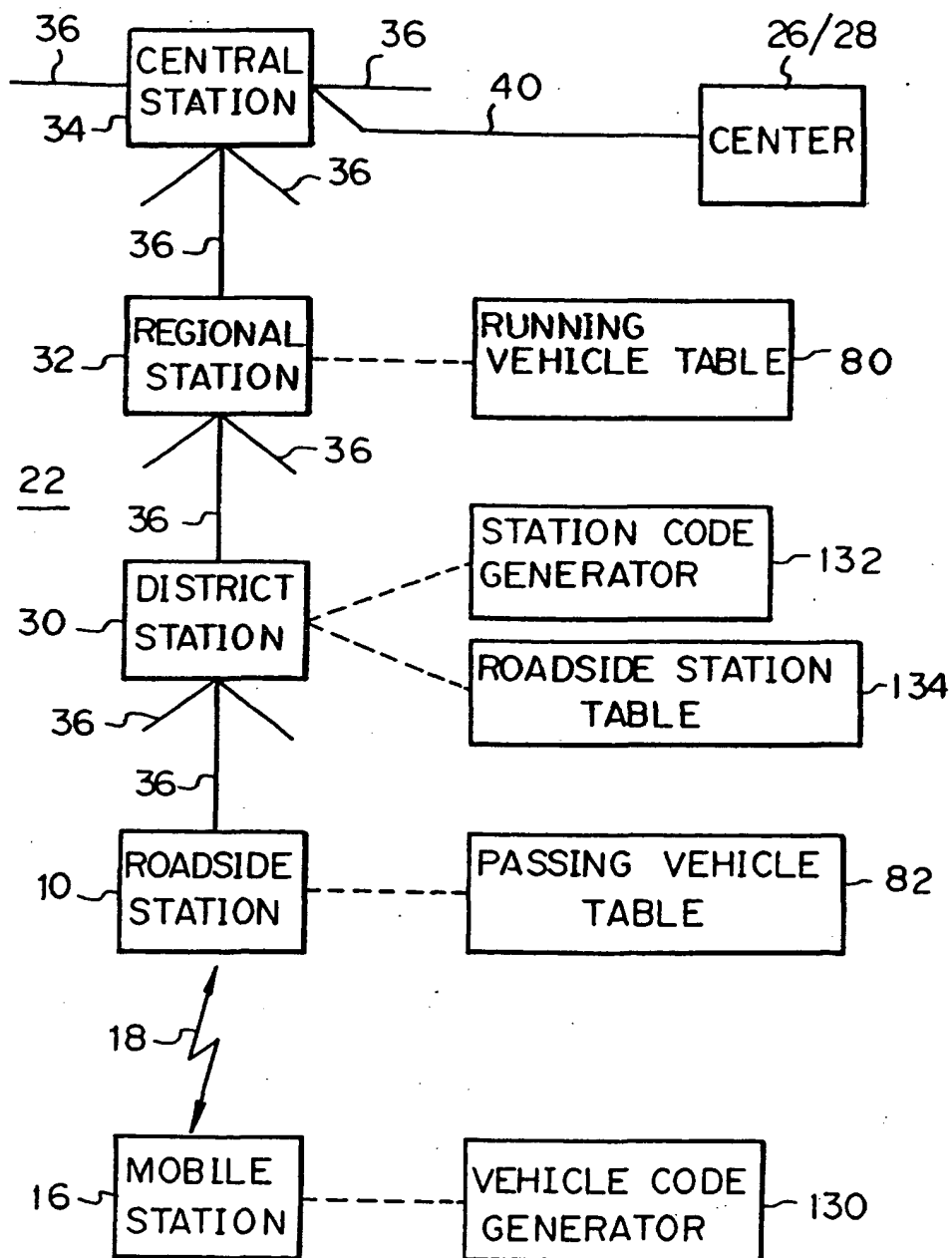


Fig. 13

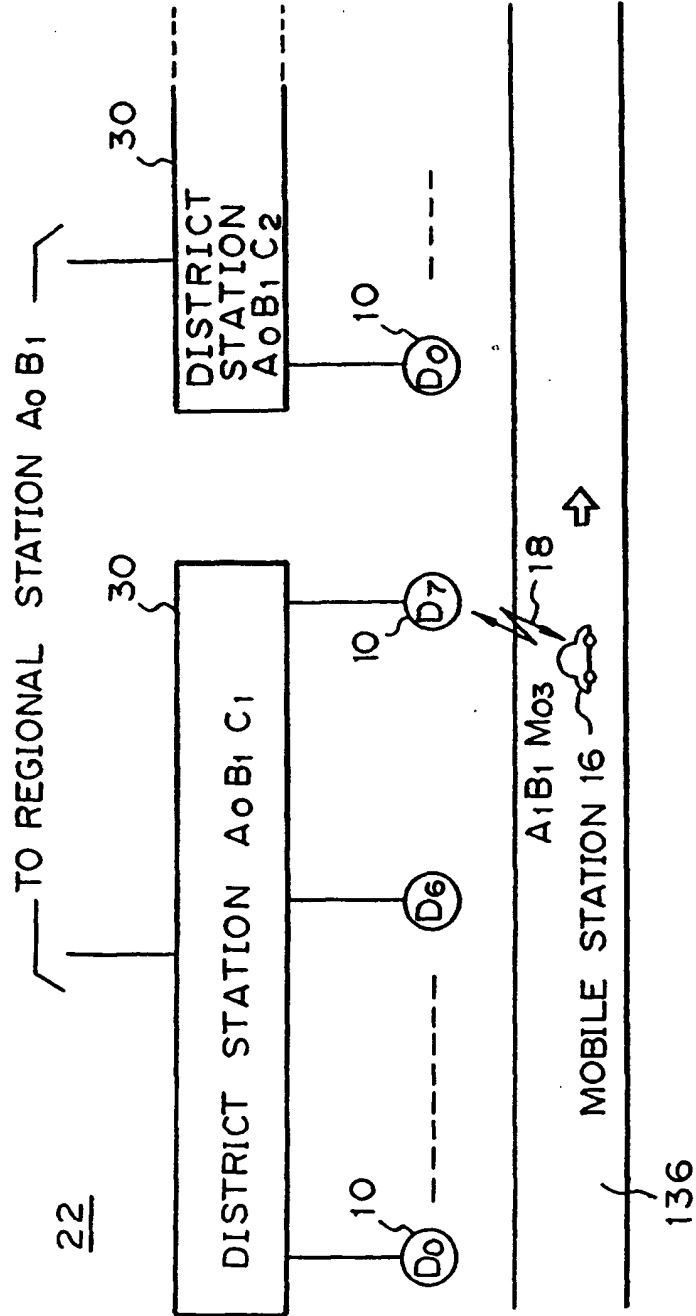


Fig. 14

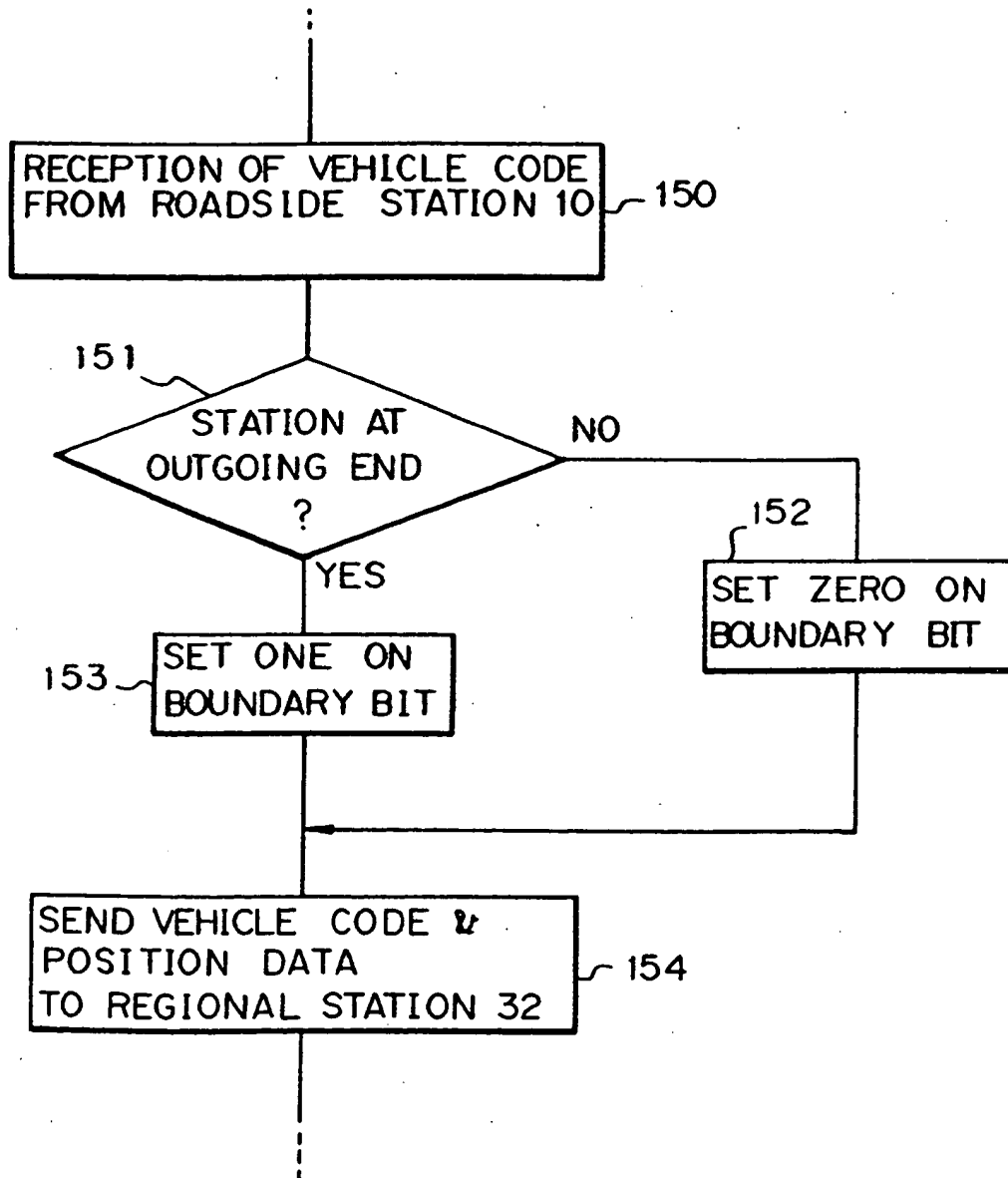


Fig. 15

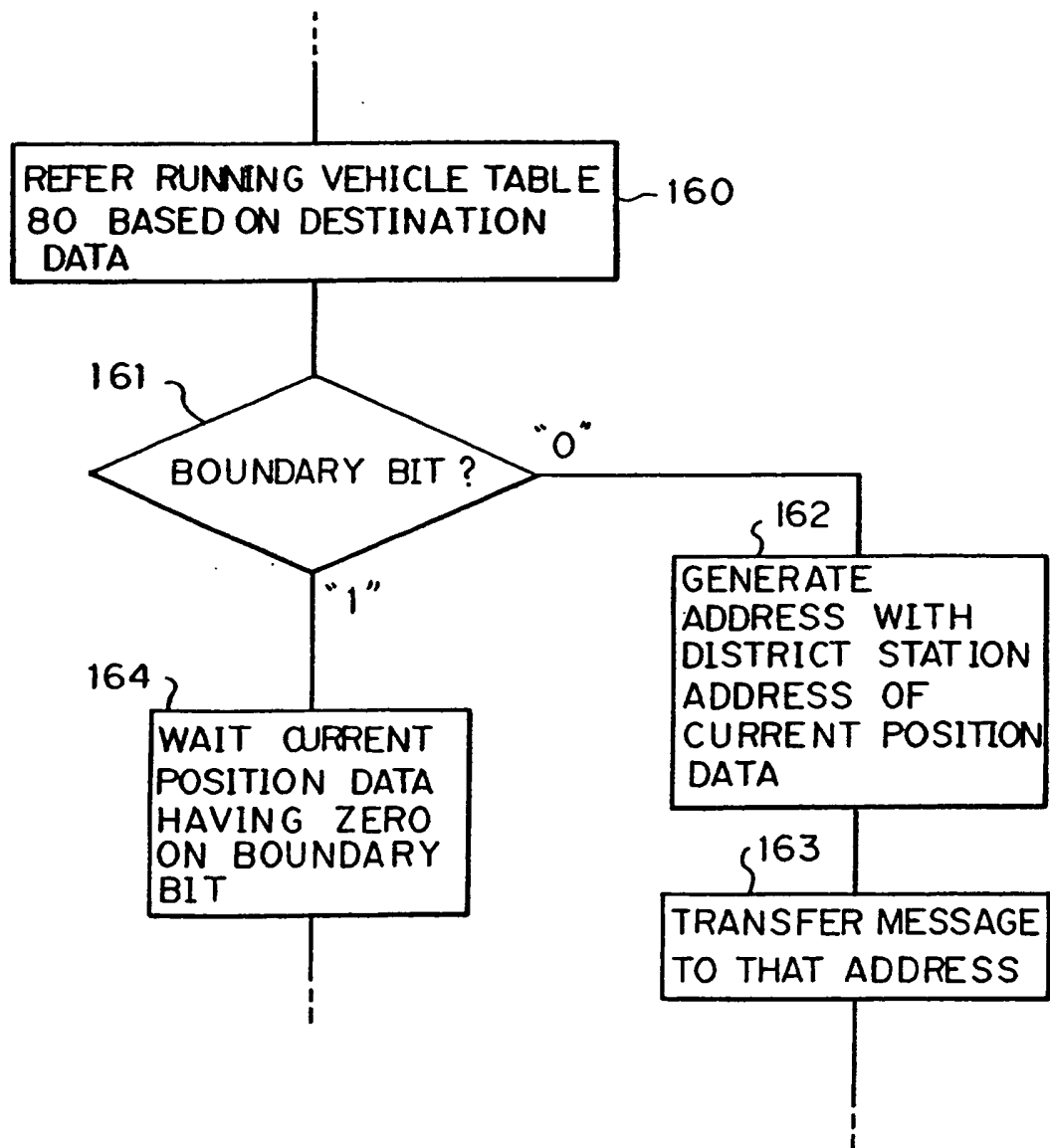


Fig. 16

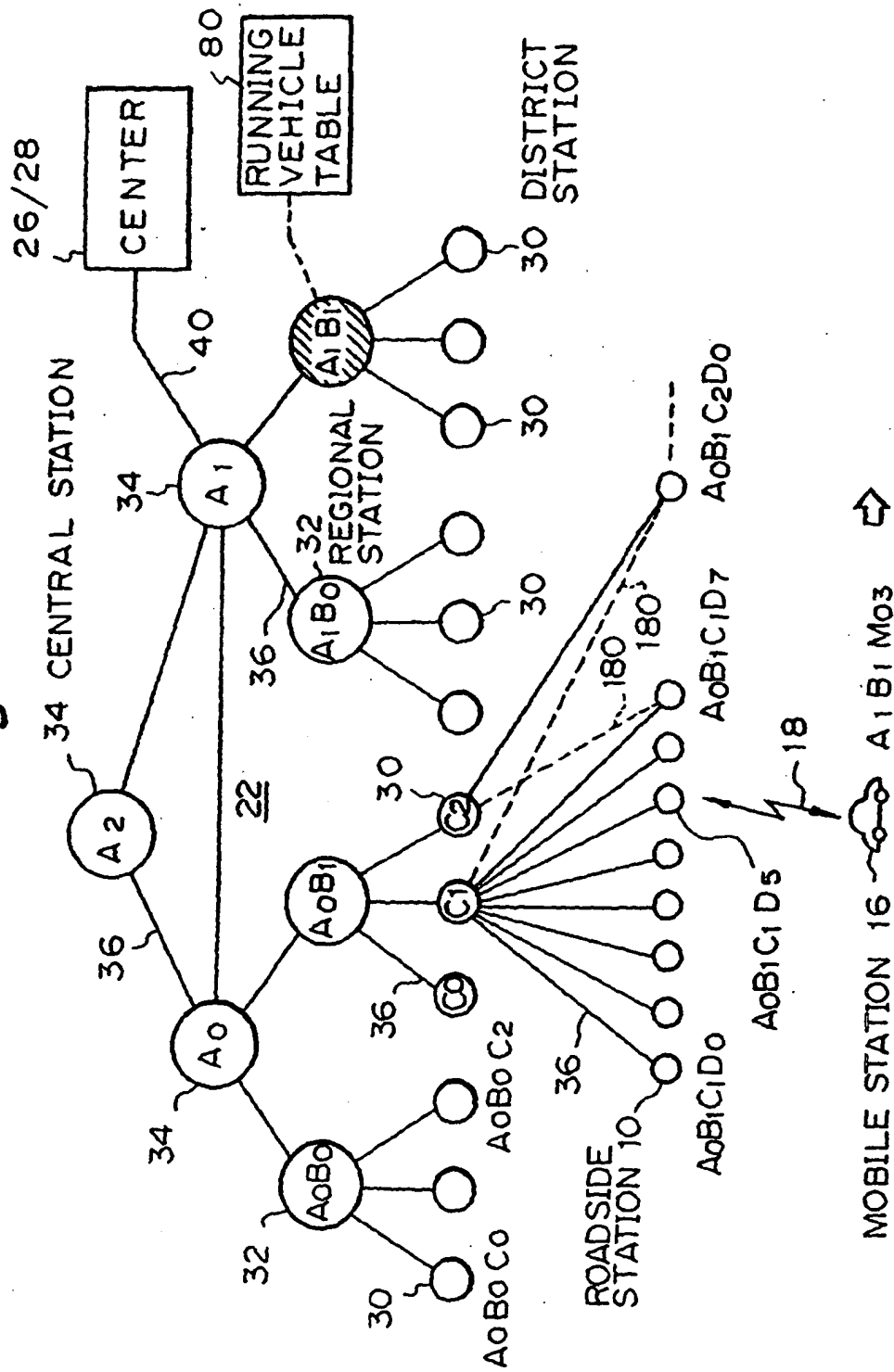


Fig. 17A

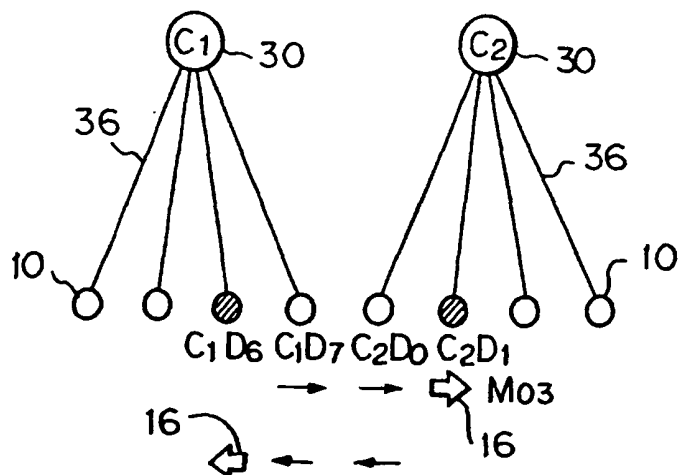


Fig. 17B

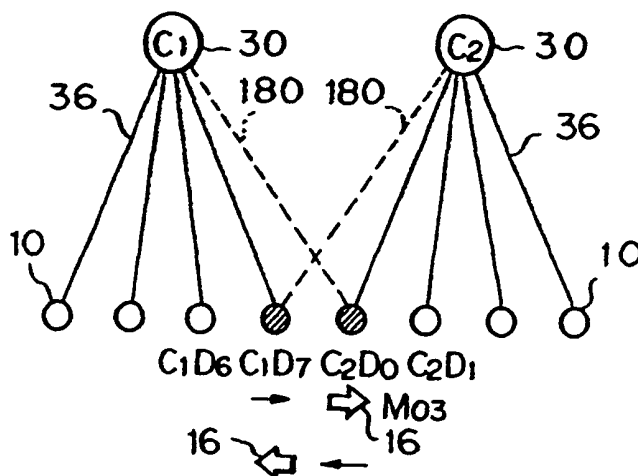


Fig. 17C

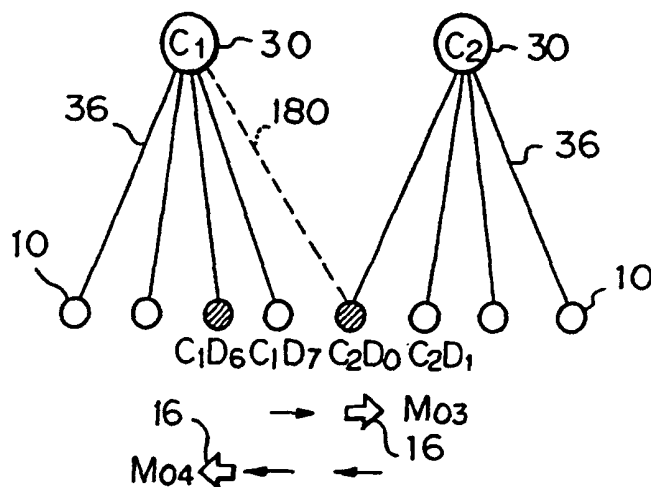




Fig. 19

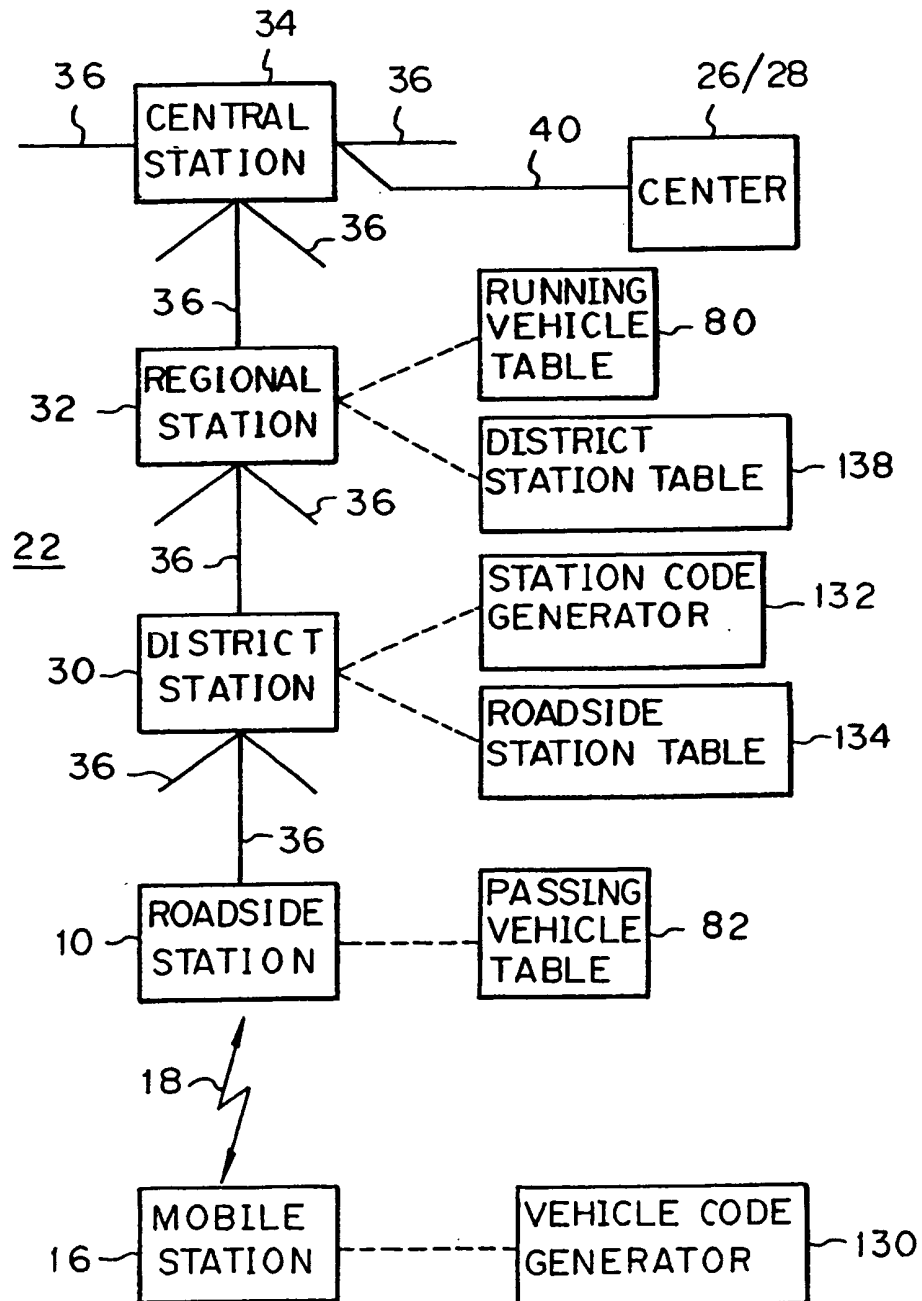


Fig. 20

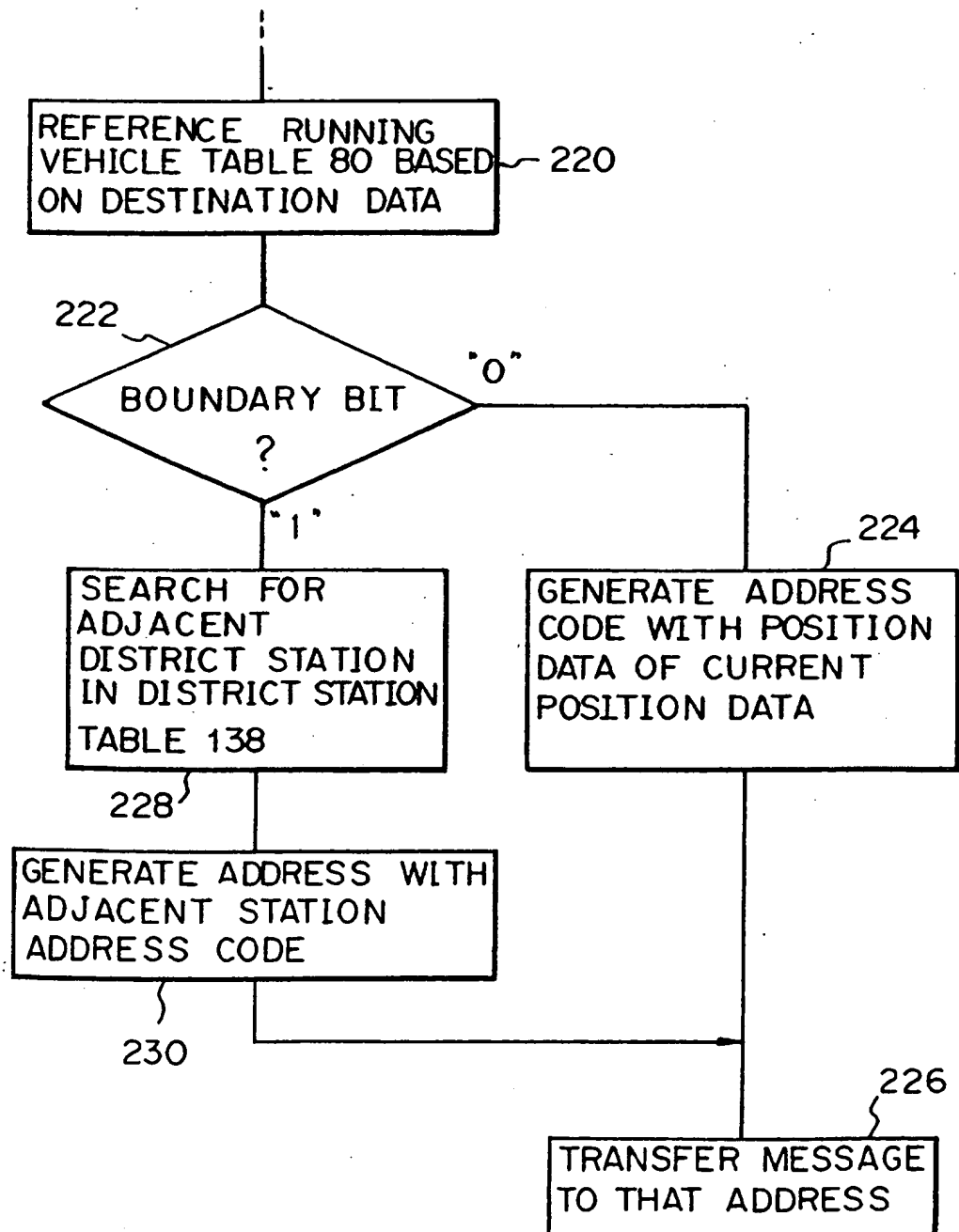


Fig. 21

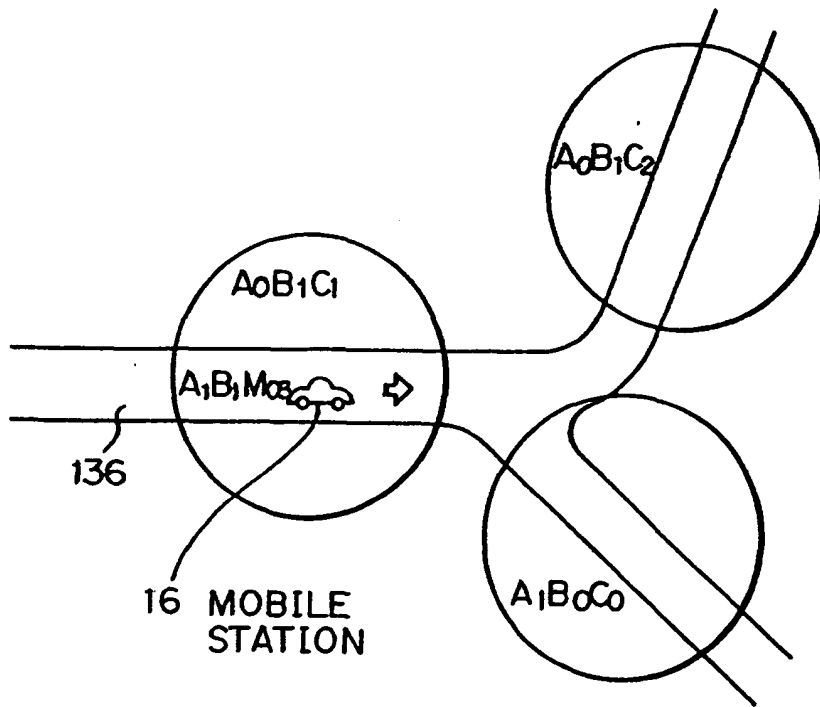


Fig. 22

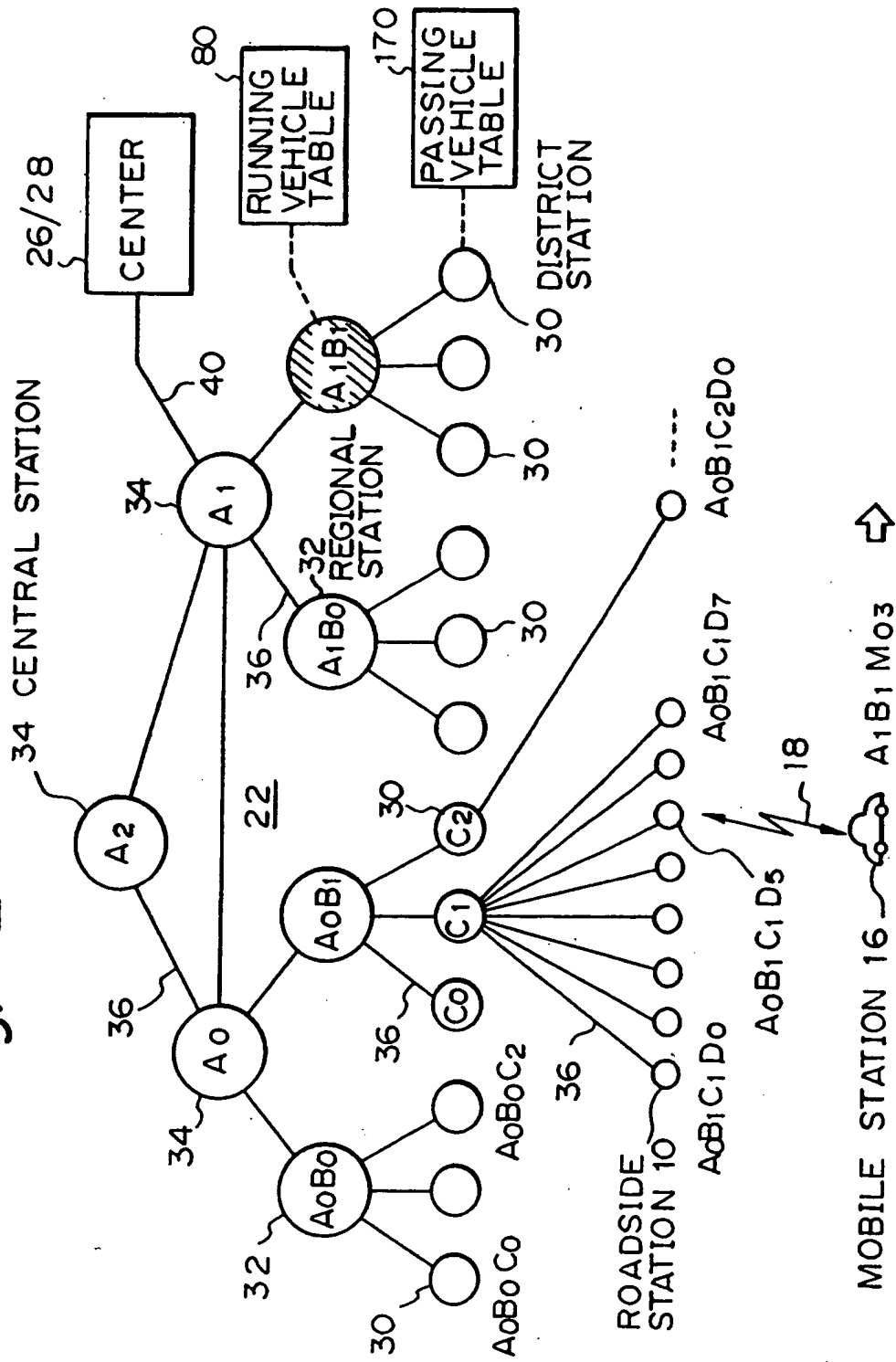


Fig. 23

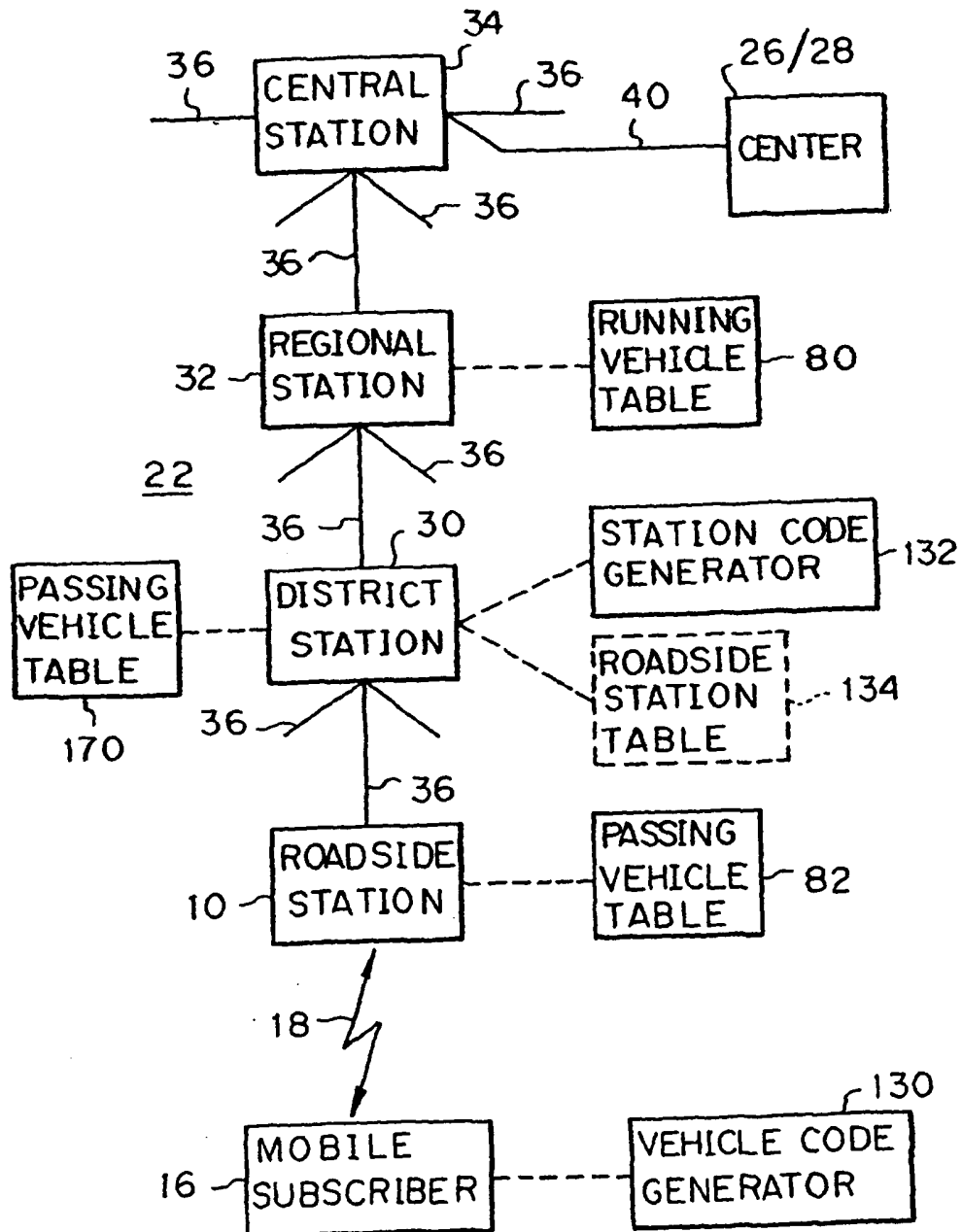
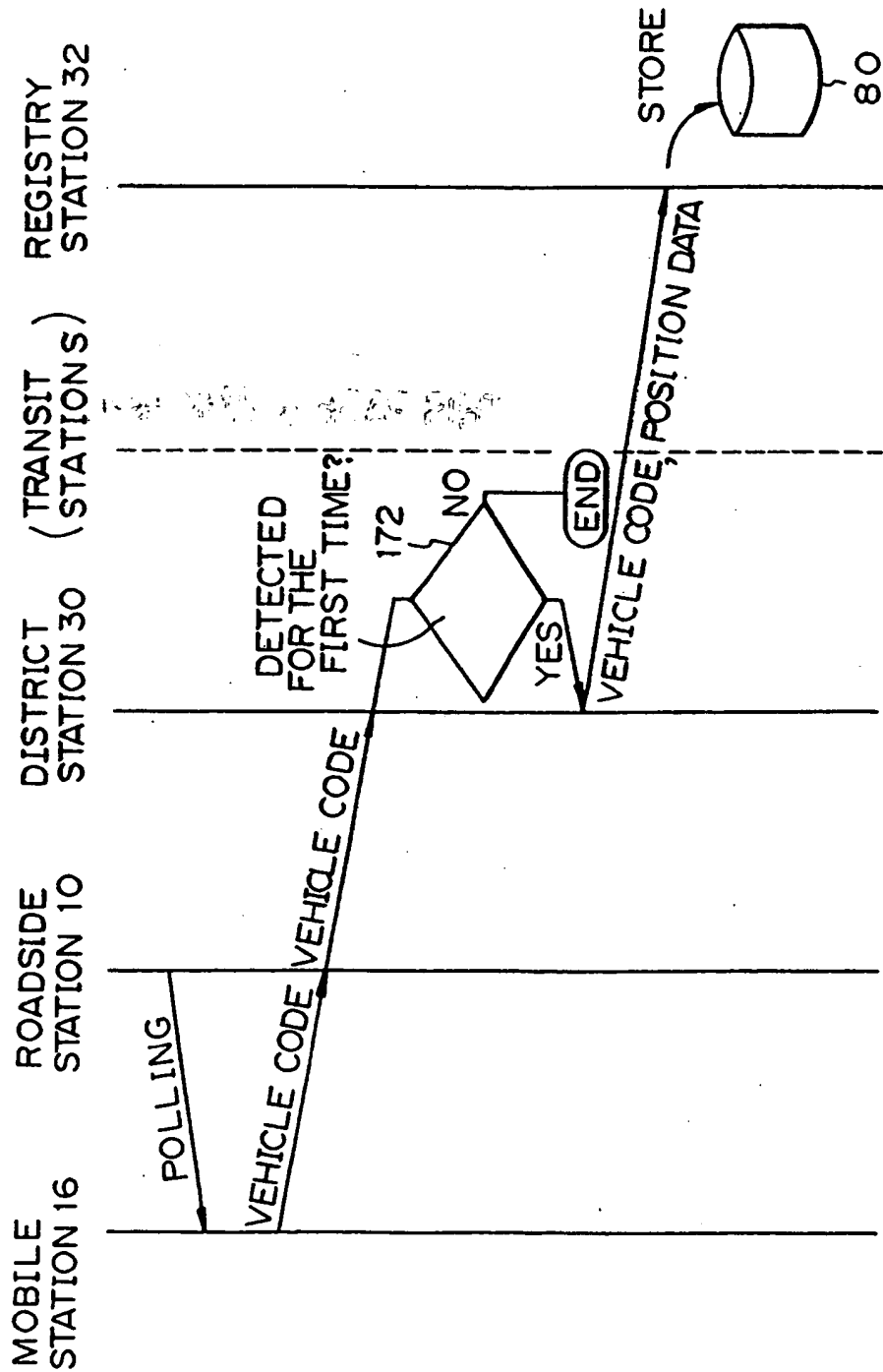
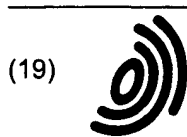


Fig. 24



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### (54) Mobile telecommunications system using distributed miniature zones

Mobiles Telekommunikationssystem mit verteilten Kleinzonen

Système de télécommunications mobiles utilisant des zones miniatures distribuées

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**EP 0 673 177 B1**

## Description

### BACKGROUND OF THE INVENTION

#### Field of the Invention

[0001] The present invention relates to a mobile telecommunications system and, more particularly, to a mobile telecommunications system advantageously applicable, but not exclusively, to telecommunications with vehicles such as motorvehicles.

#### Description of the Prior Art

[0002] Typical of prior art mobile telecommunications systems with which the present invention is particularly concerned is an automobile telephone system which is disclosed in W. R. Young, "Advanced Mobile Phone Service", Bell Syst. Tech. J. Vol. 58, No. 1, pp. 1-278, Jan., 1979. Some of prior art automobile telephone systems share a cellular concept which is such that base stations each covering a limited service zone or cell are arranged two-dimensionally and the service zones of adjoining base stations overlap each other to insure the continuity of a communication.

[0003] To terminate an incoming call at a given mobile station, it is necessary to determine the current position of the mobile station. With the prior art cellular automobile telephone system, it has been customary to cause a network to access a plurality of zones by general calling, then detect a response of a mobile station of interest to determine the current position of the mobile station, and then terminate an incoming call at that station.

[0004] In a cellular mobile communication system, different frequencies are assigned to the individual zones or cells which adjoin each other so as to avoid interference of electromagnetic waves. To effectively use a limited frequency band available, it is preferable that the zone configuration is fractioned to promote repetitive use of the same frequency. However, fractioning the zone configuration increases the number of times that the frequency should be switched over during movement of a mobile station over a plurality of zones, forcing both of the base stations and the mobile stations to bear an extra load for frequency switchover control. This problem is more pronounced as the moving speed of a mobile body increases. The only implementation available with the prior art cellular system for eliminating this problem is to broaden each zone or to increase the number of frequencies assigned. However, increasing the number of frequencies is extremely difficult in the present severe frequency assignment environment.

[0005] An automobile telephone system implemented by the cellular concept is customarily designed to implement voice communications and is therefore not always suitable for services of the kind transmitting a large amount of data at high speed. In land traffic which involves automobiles, for example, services of the kind

mentioned include a navigation service which guides automobiles along appropriate routes depending upon the degrees of congestion, weather and so forth, and an operation control service which controls the operations of a large number of automobiles collectively with efficiency. In this kind of traffic, therefore, a large amount of data have to be interchanged between on-board units and base stations at high speed. The frequency band of a transmit signal available with a prior art automobile telephone system is limited to the speech band, limiting the applicability of the system.

[0006] Further, in the prior art automobile telephone system, in response to every incoming call each base station accesses mobile stations by general calling and, after awaiting a response from a particular mobile station, terminates the call at that mobile station. This results in the need for complicated control over the termination of an incoming call and therefore in a relatively long connection setup time. With the prior art system, it is impossible to locate individual mobile bodies unless the mobile bodies are called up individually. It follows that a transport company or similar user owning a large number of vehicles cannot efficiently supervise the operations of the vehicles.

[0007] When a plurality of base stations each being communicatable with a mobile station over a radio link are distributed at spaced locations with a no-wave area intervening between nearby base stations, the base stations will be allowed to share the same frequency as the electromagnetic waves on the radio links. In a mobile communication system having such a configuration, the base station accessible to a mobile station sequentially changes as the mobile station travels and, hence, a communication with a desired mobile station cannot be adequately set up unless the system recognizes the varying position of the mobile station at all times. Moreover, even if the system accurately locates a mobile station at a certain moment, it is not warrantable that it actually stays in that position when a call meant therefore is originated. Especially, when it comes to a system applicable to ordinary roads as distinguished from thruways, a mobile body moves two-dimensionally so that estimating the future movement of a mobile body accurately so as to accomplish efficient call termination control is difficult. Moreover, it is undesirable that the traffic concentrates more on the communication which is adapted to locate mobile stations than on the primary communication traffic of the entire system.

[0008] In a mobile telecommunications system, mobile stations constantly move around without remaining in fixed positions so that a plurality of wave propagation paths exist between base stations and mobile stations. The wave propagation paths interfere with each other to cause sharp and noticeable changes in the amount of wave attenuation ascribable to the movement. Hence, in a blind area, a sufficient electromagnetic wave cannot be fed to a mobile station and it sometimes occurs that the path between a land station and a mobile

station cannot be set up despite that the land station is kept in connection to a switched telephone network. In this condition, an originating subscriber has to wait until the path to the mobile station has been set up and, in the meantime, the path between the calling terminal and the land station is held only ineffectively. When a predetermined period of time expires before the path between the land station and the mobile station is set up, the originating subscriber is informed of the unable-to-connect condition by, for example, a switched telephone network by voice. Then, the caller has to repetitively call the mobile station until the connection succeeds.

**[0009]** US-A-4 182 989 discloses a system for establishing a communication link between a ground station and each of vehicle drivers, wherein information is transferred in a compressed manner with respect to time while a vehicle moves within a limited communication area defined over a road surface by a UHV antenna. The peripheral units of the ground station are located in a series at intervals along a traffic lane. Therefore control of highways and city streets can be carried out, e.g. this system is exclusively applicable to a straight road.

**[0010]** The article "Von Zelle zu Zelle" in Funkschau, No. 7, March 1987, Munich, pages 57-59 discloses a cellular system which intends a continuous communication between cells. Thus, zones using different frequencies for data exchange are required to be partially overlapped.

**[0011]** The article "Communication protocol for mobile packet communication system using continuously allocated small zones" published in "Transaction of the Institute of Electronics, Information and communication engineers" B, Vol. 71 B, March 1988, Japan, pages 383-390, discloses a new vehicle communication system which is proposed to realize an excellent movement control of vehicles on highways. In this system, small communication zones of about 10 metres long are allocated continuously along the road, and every vehicle in the zone transmits and receives digital data through the same signal communication channel using the TDM.

#### SUMMARY OF THE INVENTION

**[0012]** It is therefore an object of the present invention to provide a new and useful mobile telecommunications system which implements high-speed telecommunications without occupying a number of frequencies.

**[0013]** It is another object of the present invention to provide a mobile telecommunications system which reduces the processing loads imposed on land stations and mobile stations while promoting effective use of a telecommunications network.

**[0014]** It is still another object of the present to provide a mobile telecommunications system which adequately supervises the conditions of mobile stations inclusive of communications with mobile stations.

**[0015]** It is yet another object of the present invention to provide, in a new mobile telecommunications system

capable of effecting high-speed telecommunications without occupying a number of frequencies, a call termination control system which enhances efficient control over the termination of a call at a desired mobile station.

**[0016]** It is a further object of the present invention to provide, in a new telemobile telecommunications system capable of effecting high-speed telecommunications without occupying a number of frequencies, a mobile station locating system which enables an originating subscriber to hold an adequate communication with a desired mobile station.

**[0017]** Present invention is defined in independent claim 1. In an embodiment of the present invention, there is provided a mobile telecommunications system comprising a plurality of base stations each being communicable with a mobile station over a radio link. The base stations are spaced apart from each other by an area in which the mobile station is substantially not responsive to an electromagnetic wave on the radio link and are therefore allowed to share a single frequency as the electromagnetic wave. A communication network accommodates the base stations and is constituted by a plurality of switching stations for switching communications to the base stations. The mobile station is registered in any one of the switching stations. Any one of the plurality of switching stations detected the mobile station reports the position of the mobile station to the switching station where the mobile station is registered. The switching station where the mobile station is registered stores data of the reported position of the mobile station. The switching station where the mobile station is registered constantly updates the stored position data in response to the position of the mobile station being detected and reported.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0018]** The objects and features of the present invention will become more apparent from the consideration of the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic block diagram showing a mobile telecommunications system using distributed miniature zones implemented as an on-road vehicle telecommunications system for road traffic;

FIG. 2 is a schematic block diagram representative of a specific hierarchical configuration of an on-road vehicle telecommunications network which is included in the system of FIG. 1;

FIG. 3 shows a specific format of a vehicle-oriented code applicable to the system of FIG. 1;

FIG. 4 indicates a specific frame format also applicable to the system of FIG. 1;

FIG. 5 is a diagram demonstrating a specific communication sequence between a mobile station and a roadside station included in the embodiment of

FIG. 1;

FIG. 6 is a view schematically showing a mobile telecommunications system using distributed miniature zones;

FIG. 7 is a schematic diagram representative of an alternative hierarchical configuration of the on-road vehicle telecommunications network;

FIG. 8 is a diagram demonstrating a specific sequence for locating a mobile station;

FIG. 9 is a diagram demonstrating a specific sequence for terminating a call at a mobile station;

FIG. 10 is a diagram schematically showing a specific paging group configuration of roadside stations;

FIG. 11 is a schematic block diagram representative of another specific hierarchical configuration of the on-road vehicle telecommunications network;

FIG. 12 indicates another specific format of the vehicle-oriented code;

FIG. 13 is a diagram schematically showing an embodiment of the present invention for detecting a roadside station located at the outgoing end of a coverage area;

FIG. 14 is a flowchart showing a procedure for a district station to report the position of a mobile station to a registry station in the embodiment of FIG. 13;

FIG. 15 is a flowchart demonstrating a specific procedure associated with an embodiment in which a message address is generated when a registry station terminates an incoming call at a mobile station;

FIG. 16 is a schematic view showing an alternative embodiment of the mobile telecommunications system using distributed miniature zones;

FIGS. 17A, 17B and 17C are schematic diagrams individually showing embodiments of single subordination and double-subordination of an end roadside stations which lies in the coverage area of a district station;

FIG. 18 is a schematic diagram showing an alternative embodiment of the mobile telecommunications system using distributed miniature zones in accordance with the present invention;

FIG. 19 is a block diagram schematically representative of an alternative hierarchical configuration of the on-road vehicle telecommunications network;

FIG. 20 is a flowchart associated with an embodiment of the present invention in which a message address is generated when a call is to be terminated at a mobile station;

FIG. 21 is a diagram schematically showing how a mobile station is called by adjacent district stations in the system shown in FIG. 18;

FIG. 22 is a schematic diagram showing how a mobile station is located in an alternative embodiment of the mobile telecommunications system using miniature zones in accordance with the present invention;

FIG. 23 is a schematic block diagram representative of an alternative hierarchical configuration of the on-road vehicle telecommunications network;

FIG. 24 is a diagram schematically indicating another specific sequence for locating a mobile station;

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] Referring to FIG. 1 of the drawings, a mobile telecommunications system embodying the present invention is shown and implemented as an on-road vehicle telecommunications system applicable to land traffic, especially road traffic which involves automobiles and other similar vehicles. As shown, a plurality of base stations 10, in the following example referred to as roadside stations 10 are located along a road such as an ordinary road or a thruway at the intervals of several hundred meters or several kilometers, for example. The distance between nearby roadside stations 10 may be suitably selected in matching relation to the regulation speed of the road, for example. Each roadside station 10 is a land station which serves as a base station capable of communicating with a subscriber vehicle 12 over a radio channel.

[0020] Each roadside station 10 covers a limited service area or zone 20 and has a transmitter/receiver 14 for transmitting and receiving an electromagnetic wave 18 from an on-board unit, or mobile station, 16 (FIG. 2) which is mounted on a subscriber vehicle 12 that is present in the zone 20. A characteristic feature of the illustrative embodiment is that the roadside stations 10 are distributed at intervals and each zone 20 is far smaller than the interval between nearby roadside stations 10. The diameter of each zone 20 may be of the order of several ten meters to a hundred meters, for example. Therefore, the nearby zones 20 leave therebetween an area in which the mobile station 16 is substantially not responsive to any of the electromagnetic waves 18 issuing from the roadside stations 10, i. e. a no-wave area. A vehicle 12 can communicate with any of the roadside stations 10 only when it is operated within the zone 20 defined by the roadside station 10. This communication occurs at a high speed.

[0021] Having the above configuration, the illustrative embodiment allows the nearby roadside stations 10 to use the same frequency repetitively and effectively. Basically, therefore, the radio links between the roadside stations 10 and the mobile stations 16 included in the entire system can be implemented by a single frequency. A system with which full-duplex communication is available uses a pair of frequencies, one for an up-going channel and the other for a down-going channel. This eliminates the need for the switchover of frequency which is indispensable with the prior art cellular system. Having these characteristic features, the system will be referred to as a distributed miniature zone system while each zone 20 will be referred to as a miniature zone.

**[0022]** The roadside stations 10 form a part of an on-road vehicle telecommunications network, e.g. the communication system of the present example, 22 and, in this particular embodiment, they are capable of accessing a switched telephone network 24, a packet switching network or similar data switching network 25, or other similar telecommunications facilities such as a system center 26 and a user center 28 via the on-road vehicle telecommunications network 22. Adopting a hierarchical configuration as shown in FIG. 2 by way of example, the on-road vehicle telecommunications network 22 performs switching between the telephone network 24, data switching network 25 and centers 26 and 28 and the individual mobile stations 16, as described in detail later.

**[0023]** The distributed miniature zone telecommunications system described above promotes high-speed communication between the mobile stations 16 and the roadside stations 10 and, therefore, implements a variety of services including high-speed data communications. Typical examples are a navigation service for guiding an automobile or similar vehicle 12 along an adequate route which may depend on the degree of traffic congestion and weather, and a data communication service for allowing the mobile stations 16 to communicate with the center 26 or 28 via the telecommunications network 22 so that the operations of a great number of vehicles 12 may be managed efficiently.

**[0024]** Referring the FIG. 2, the hierarchy of the on-road vehicle telecommunications network 22 is constituted by district stations or offices 30 each accommodating a plurality of roadside stations 10 which are distributed in a certain district, regional stations or offices 32 each accommodating a plurality of district stations 30 over a certain area, and central stations 34 each accommodating a plurality of regional stations 32, wherein the district stations 30, the regional stations 32, and the central stations 34 can all be understood as switching stations in this present example. The associated stations 30, 32 and 34 inclusive of the roadside stations 10 will be collectively called a land station hereinafter. In the illustrative embodiment, the channels between the associated district station 30, regional station 32 and central station 34 are configured in a tree-like network which is constituted by basic trunks, transversal trunks or similar trunks 36. On the other hand, the central stations 34 are interconnected by a mesh type network. The present invention, of course, is not limited to such a network configuration and may be practiced with any other kind of hierarchy which matches with the nature of a road, e. g., an ordinary road or a thruway or a linear network.

**[0025]** The trunks 38 terminating at the switched telephone network 24 and data switching network 25 are accommodated in the central stations 34, for example. The system center 26 plays the role of a data processing system assigned to the navigation of the subscriber vehicles 12, for example. The user center 28 serves as a

data processing system available for a particular customer to supervise the operations of, among the subscriber vehicles 12, those which belong to the customer. The system center 26 and user center 28 are connected to the central stations 34 by trunks 40. These centers 26 and 28 may of course be connected to the regional centers 32 or the district centers 30.

**[0026]** The central station 34, regional station 32 and district station 30 have their own station codes. By representing the individual codes assigned to the central station 34 and regional station 32 by hierarchy, a registry land station code 52 (FIG. 3) is formed. For user owning a great number of subscriber vehicles, the district station code may be replaced with a user code which is particular to the user. The mobile station 16 mounted on each subscriber vehicle 12 is registered in any of the district station 32 and provided with a unique mobile station code 54 there. Hence, in the nationwide scale, each on-board unit or mobile station 16 is designated by a land station code 52 and a mobile station code 54. It is to be noted that the subscriber vehicles may be registered in the central stations or district stations.

**[0027]** As shown in FIG. 3, in the illustrative embodiment, a vehicle-oriented code for specifying a mobile station 16 is made up of a static code 50 and a dynamic code 60. The static code 50 specifies the mobile station 16 registered in the regional station 32 and consists of the land station code 52, the mobile station code 54 and a system code 56 adapted to distinguish the entire system from other systems. Specifically, the system code 56 identifies this system in distinction from the other systems and is omissible within this system. Hence, apart from the function of providing a mobile station 16 with an identification number within the system, the static code 50 is closely related to the number system of calls which the mobile station 16 may receive from the telephone network 24, data switching network 25 and centers 26 and 28.

**[0028]** The dynamic code 60 is associated with the moving state of the subscriber vehicle 12 and effectively used to grasp the current condition of the vehicle 12 for a navigating purpose. In this sense, the dynamic code 60 is a code unique to a subscriber vehicle 12 and associated with the district or region in which the vehicle 12 is operated as well as its travelling condition. The dynamic code 60, therefore, plays an important role in allowing any of the telephone network 24, data switching network 25 and centers 26 and 28 to locate a vehicle 12 for a paging purpose and supplying a vehicle 12 with guide information for routing it to a destination. In the illustrative embodiment, the dynamic code 60 includes a destination code 62 representative of a destination of the subscriber vehicle 12 and an first position information (64) hereafter referred to running area code 64 in this illustrative embodiment representative of an area in which the vehicle 12 and thereby the position of the mobile station 16 connected thereto is running. The running area code 64 is constituted by the codes which are in-

dividually assigned to the central station 34, regional station 32, and district station 30. The area code 64 may further include a link code which shows a communication link being set up.

**[0029]** As shown in FIG. 2, in the illustrative embodiment, the regional station 32 has a running vehicle table 80. The table 80 stores data representative of particular areas in which the subscriber vehicles 12 registered in the associated regional station 32 are running, on a station basis. The table 80 also stores data associated with other subscriber vehicles 12 which are running in the coverage area of the regional station 32, on a registry station basis. These data stored in the table 80 are updated every moment. A similar vehicle table may also be installed in each district station 30 or central station 34, as exemplarily indicated by a phantom line 84 in relation to the district station 30.

**[0030]** As FIG. 1 schematically indicates, each roadside station 10 has a memory 42 which includes areas for storing a passing vehicle table 82 (FIG. 2) and information to be interchanged between the roadside station 10 and the mobile stations 16. The passing vehicle table 82 holds data associated with the subscriber vehicles 12 which travel through the miniature zone 20 which the roadside station 10 covers. These data include the vehicle specific codes 50 and 60 and are constantly updated as the subscriber vehicles 12 pass through the miniature zone 20.

**[0031]** In the illustrative embodiment, the mobile station 16 is mounted on an automobile or similar subscriber vehicle 12 and transmits/receives navigation information, operation supervisory information and other similar data, messages and video signals with the roadside stations 10 while allowing an occupant to see such signals visually and/or auditorily. Preferably, the mobile station 16 is provided with a video display, facsimile transceiver, vocoder and other similar equipment for interfacing the roadside stations 10 to a vehicle occupant by means of pictures and speeches. Further, the mobile station 16 may be provided with an automatic operation control function which governs the steering mechanism of the subscriber vehicle 12. The mobile station 16 has a random number table function so that the road station 10 may select an idle channel out of a plurality of channels assigned to the link 18 between the stations 10 and 16 by polling.

**[0032]** In this embodiment, a communication between the on-board mobile station 16 and the base station 10 is effected by polling which uses a frame 100 having a format which is shown in FIG. 4. In the illustrative embodiment, the frame 100 has a period of 683 milliseconds (ms) and a signalling rate of 512 kilobits per second, a plurality of channels being multiplexed in a great number of time slots of the frame 100. In principle, a necessary bidirectional communication is completed within one frame period. The radio links 18 are implemented by a single frequency. In the case of full-duplex communication, each of an up-going and a down-going

channel is implemented by a different frequency. Nevertheless, since such frequencies are fixed, a subscriber vehicle 12 will be served by the same frequencies throughout the distributed zones 20 of the roadside stations 10. As shown in FIG. 4, the frame 100 is headed by an introductory field 102 which includes a preamble, a synchronizing signal, a polling identification (ID) signal, and a code assigned to a roadside station 10. As shown in FIG. 5, the roadside station 10 polls the mobile station 16 being operated in its own zone 20 at a predetermined period by using the introductory field 102 of the frame 100. The mobile station 16 is held in a receive mode while in an idle state and is brought into a transmit mode when the introductory field 102 is fully received.

**[0033]** The introductory field 102 is followed by a subscriber ID field 104 which allows the mobile station 16 to send its own vehicle codes 50 and 60 while allowing the roadside station 10 to recognize it. Advantageously, two blocks may be sent repetitively so as to achieve a far higher subscriber recognition rate. In response to the polling, the mobile station 16 selects an idle channel out of a plurality of channels by using the random number table. The static subscriber code 50 and a service function code are transmitted to the roadside station 10 over the idle channel (see FIG. 5).

**[0034]** In the illustrative embodiment, the subscriber ID field 104 is followed by a multicast communication field 106. By using this field 106 of the frame 100, the roadside station 10 sends to the mobile station 16 traffic information and other beacon type dynamic navigation information as well as registration response signal (ACK or NACK) (FIG. 5). If the channel selected by the mobile station 16 does not conflict with another channel, the roadside station 10 registers it and sends an ACK signal to the mobile station 16.

**[0035]** A vehicle communication field 108 is provided next to the multicast field 106 of the frame 100. In the illustrative embodiment, as shown in FIG. 5, a full-duplex communication is held between the roadside station 10 and the mobile station 16 by using the vehicle communication field 108. For the full-duplex communication, an up-going and a down-going channel each having a different frequency and selected by the roadside station 10 are used. However, the subscriber vehicle 12 is served by the same frequencies in the zones 20 which are defined by the nearby roadside stations 10. The full-duplex communication, of course, may be replaced with half-duplex or one-way communication. During the vehicle communication field 106, the mobile station 16 and the system center 26 and/or user center 28 interchange navigation information, operation supervisory information or similar data, message, and video signal. Such information is imparted to the vehicle occupant in the form of a picture or a speech. The mobile station 16 may communicate with any of the switched telephone network 24, data switching network 25, and another mobile station 16 which is served by this system, in the same manner as with the center 26 or 28.

**[0036]** The roadside station 10 may store in the passing vehicle table 82 the data associated with the subscriber vehicles 12 and obtained from the mobile stations 16 present in the zone 20 at each polling period. These data are sent from the roadside station 10 to the district station 30, regional station 32, or central station 34. The station 30, 32 or 34 then stores the incoming data in the running vehicle table 80, for example. Hence, the running vehicle table 80 of the regional station 32, for example, is constantly updated by new data.

**[0037]** Information sent from the center 26 or 28, switched telephone network 24 or data switching network 25 and meant for a certain mobile station 16 is temporarily stored in any of the stations, e. g. the memory 42 of the roadside station 10. The roadside station 10 compares a destination code associated with the information with the static vehicle codes 50 obtained from the mobile stations 16 which are present in the associated coverage area. If the destination code is coincident with any of the static vehicle codes 50, the roadside station 10 transmits the information stored in the memory 42 to the mobile station 16 for which the information is meant by using the down-going channel of the vehicle communication field 108 of the frame 100. Information sent from a certain mobile station 16 to the roadside station 10 is temporarily stored in the memory 42. The up-going information is transferred to the center 26 or 28, data switching network 25 or switched telephone network 24 over the on-road vehicle telecommunications network 22 later.

**[0038]** The vehicle communication field 108 of the frame 100 is followed by an end-of-communication field 110 for transmitting an up-going and a down-going answer signal (FIG. 5). This signal is adapted to confirm the end of communication and not to confirm the content of information.

**[0039]** By the above procedure, one frame 100 of communication is completed while the subscriber vehicle 12 runs through the service zone 20 which is managed by the roadside station 10. While the subscriber vehicle 12 runs in the no-wave area defined between two nearby zones 20, the mobile station 16 cannot communicate with the on-road vehicle communications network 22. Due to the use of a single frequency, the system may bring up the image of a conventional leakage coaxial cable broadcasting system. However, the illustrative embodiment is implemented as a one-to-one communication system and not a broadcasting system and is clearly distinguishable over a leakage coaxial cable broadcasting system due to the presence of no-wave areas.

**[0040]** In principle, this particular embodiment is constructed such that one communication completes while the subscriber vehicle 12 exists in a certain miniature zone 20. The roadside stations 10 are distributed along a road, whether it be an ordinary road or a thruway, at intervals which allow the subscriber vehicle 12 to complete a substantial amount of communications while run-

ning through some miniature zones 20 which have the no-wave areas therebetween. Stated another way, such a distant arrangement of roadside stations 10 makes it possible even for mobile stations 16 whose communication traffic is heavy to achieve desired communications satisfactorily.

**[0041]** Referring to FIG. 7, an alternative illustrative embodiment is shown in which the mobile stations 16 are individually registered in particular land stations beforehand, more specifically the on-road vehicle telecommunications network 22 of such an alternative embodiment. In this network 22, each mobile station 16 has a vehicle code generating unit 130 while each district station 30 has a station code generating unit 132. In the figure, similar components or structural elements are designated by the same reference numerals, and redundant description will be avoided for simplicity.

**[0042]** The vehicle code generating section 130 of the mobile station 16 generates a vehicle code which is assigned to the mobile station 16. The vehicle code includes a land station code 52 (FIG. 3) representative of a particular station in which the mobile station 16 is registered, and a mobile station code 54 assigned to the mobile station 16. These codes are set in the vehicle code generating section 130 and, in response to polling from any of the roadside stations 10, read thereout of to be transmitted.

**[0043]** As shown in FIG. 6, assume that a certain mobile station 16 is registered in one,  $B_1$ , of regional stations which are subordinate to a central station  $A_1$ . Further, assume that the land station code 52 assigned to the regional station 32 is " $A_1B_1$ ", and the mobile station code 54 assigned to the mobile station 16 within the regional station 32 is " $M_{03}$ ". Then, the mobile station 16 is designated by a static vehicle code " $A_1B_1M_{03}$ ".

**[0044]** Given one,  $C_1$ , of the district stations belonging to the regional station  $A_0B_1$  accommodates eight roadside stations 10 which are designated by station codes  $D_0$  to  $D_7$ , respectively, the sixth roadside station 10 as counted from the left in FIG. 6 is designated by a station code " $A_0B_1C_1D_5$ ". When the mobile station 16 whose static vehicle code 50 is " $A_1B_1M_{03}$ " is polled by the roadside station  $A_0B_1C_1D_5$  while running through the zone 20 of that roadside station, the mobile station 16 returns an ID code " $A_1B_1M_{03}$ " to the roadside station  $A_0B_1C_1D_5$  as the roadside station code 52 and mobile station code 54.

**[0045]** As the mobile station 16 running in a direction indicated by an arrow in the figure enters the zone 20 as defined by the next roadside station  $A_0B_1C_1D_6$ , it is again polled by the roadside station  $A_0B_1C_1D_6$  and, in response, returns its vehicle code " $A_1B_1M_{03}$ ". In this manner, as the mobile station  $A_1B_1M_{03}$  moves in a particular direction, the successive roadside stations 10 on the route sequentially receives the vehicle code " $A_1B_1M_{03}$ " from the mobile station  $A_1B_1M_{03}$ .

**[0046]** More specifically, as shown in FIG. 7, the district station 30 of this embodiment has a station code

generating unit 132 for generating a land station code 52 which designates the district station 30 and a roadside station code which designates a roadside station subordinate to the station 30. For example, the district station  $A_0B_1C_1$  shown in FIG. 6 has a land station code " $A_0B_1C_1$ " set in its station code generating unit 132. The vehicle code " $A_1B_1M_{03}$ " of the mobile station 16 received by the roadside station  $A_0B_1C_1D_5$  is once stored in the passing vehicle table 82 (FIG. 7) while being transferred to the district station, or upper layer station,  $A_0B_1C_1$ . As shown in FIG. 8, as the district station  $A_0B_1C_1$  determines that the mobile station 16 with the vehicle code " $A_1B_1M_{03}$ " is registered in the regional station  $A_1B_1$  which in turn is subordinate to the central station  $A_1$  as indicated by the vehicle code " $A_1B_1M_{03}$ ", it transfers the vehicle code " $A_1B_1M_{03}$ " to the regional station  $A_1B_1$ . The district station  $A_0B_1C_1$  also sends to the regional station  $A_1B_1$  information representative of its own position and a position of the roadside station 10 which has detected the mobile station 10, i. e. information indicative of the current position of the mobile station 16. This position information includes the land station code " $A_0B_1C_1$ " and roadside station code " $D_5$ " as the running area code 64 of the dynamic vehicle code 60.

**[0047]** Switching stations lying above the district station  $A_0B_1C_1$  such as the regional station  $A_0B_1$  and central stations  $A_0$  and  $A_1$  determine the destination of the mobile station position data on the basis of the vehicle code " $A_1B_1M_{03}$ " and then repeats it to the station in which the mobile station 16 is registered (hereinafter referred to as a registry station for convenience), i. e. the regional station  $A_1B_1$  in this example. Receiving the mobile station position data in the form of the static vehicle code 50 and dynamic vehicle code 60, the registry station  $A_1B_1$  identifies the mobile station 16 of interest, i. e., the mobile station  $M_{03}$  as represented by the mobile station code 54 and then stores the position data in a particular location of the running vehicle table 80 which is allocated to the station  $M_{03}$ .

**[0048]** The current position data associated with the mobile station 16 is constantly updated. In this particular embodiment, every time any of the roadside stations 10 detects a mobile station such as  $M_{03}$ , the arrival is reported from the district station 30 to the registry station  $A_1B_1$  in which the mobile station  $M_{03}$  is registered. This updates the running vehicle table 80 of the registry station  $A_1B_1$  as to the mobile station  $M_{03}$ .

**[0049]** In the illustrative embodiment, every time the mobile station 16 travels over two consecutive roadside stations 10, its position is reported to the registry station where it is registered. The current position data to be sent to the registry station may include a roadside station code, i. e. " $D_5$ " in this example. Assuming that the mobile station  $A_1B_1M_{03}$  has moved away from the miniature zone 20 of the roadside station  $A_0B_1C_1D_5$  to the miniature zone 20 of next roadside station  $A_0B_1C_1D_6$ , then the station  $A_0B_1C_1D_6$  detects it by polling, stores

the mobile station code " $A_1B_1M_{03}$ " in the passing vehicle table 82, and reports it to the district station  $A_0B_1C_1$ . In response, the district station  $A_0B_1C_1$  informs the registry station  $A_1B_1$  of the new position of the mobile station  $A_1B_1M_{03}$  by using a running area code " $A_0B_1C_1D_6$ " which includes the roadside station code " $D_6$ ". While this kind of system needs a relatively large amount of communication traffic for reporting the current position of the mobile station 16 and imposes relatively heavy updating and storing loads on the registry station, it is capable of measuring the varying position of the mobile station 16 with accuracy at all times.

**[0050]** Alternatively, an arrangement may be made such that when any of the district stations 30 has detected the particular mobile station  $M_{03}$  for the first time through any of its associated roadside stations 10, the arrival is reported to the registry station  $A_1B_1$  where the mobile station  $M_{03}$  is registered. In this case, the running area code 64 (FIG. 3) does not have to include the roadside station code. Specifically, assume that the mobile station  $A_1B_1M_{03}$  has moved away from the last roadside station  $A_0B_1C_1D_7$  subordinate to the district station  $A_0B_1C_1$  to the zone 20 which is defined by the first roadside station  $A_0B_1C_2D_0$  of the next district station  $A_0B_1C_2$ . Then, the roadside station  $A_0B_1C_2D_0$  reports the vehicle code 50 of the mobile station  $A_1B_1M_{03}$  to the district station  $A_0B_1C_2$  which then registers it in the passing vehicle table 82. At this instant, the district station  $A_0B_1C_2$  checks the passing vehicle table 82 to see if the vehicle code " $A_1B_1M_{03}$ " has been stored in the table 82 in the past. If it has not been stored in the table 82, the district station  $A_0B_1C_2$  transfers the current position data of the mobile station  $A_1B_1M_{03}$  to the registry station  $A_1B_1$  via the associated regional station  $A_0B_1$ . Here, the station code " $A_0B_1C_2$ " which ends with the district station code suffices for the current position data. This alternative system is practicable with a minimum of communication traffic for reporting the current position of the mobile station 16, while simplifying the supervisory procedure required of the registry station.

**[0051]** A reference will be made to FIG. 9 for outlining a sequence available with this particular embodiment to allow a call from the center 26 or 28 to arrive at the mobile station  $A_1B_1M_{03}$  by using the mobile station position data which is constantly updated by the registry station  $A_1B_1$ . A message destined to the mobile station  $A_1B_1M_{03}$  is sent from the center 26 or 28 to the registry station  $A_1B_1$  via the central station 34, together with a header in the form of a static vehicle specific code 50 which includes a destination code " $A_1B_1M_{03}$ ". This message transfer is effected by causing each transit or tandem station to identify the destination code " $A_1B_1M_{03}$ ". On reception of the message together with the header, the registry station  $A_1B_1$  determines whether or not the destination or mobile station  $A_1B_1M_{03}$  is qualified as to the registration on the basis of the destination code and, if it is qualified, temporarily stores the message in a memory (not shown) (140). Although not shown in the

figure, the registry station  $A_1B_1$  returns an answer for confirmation to the center 26 or 28.

[0052] Then, the registry station  $A_1B_1$  references the running vehicle table 80 to determine the current position of the mobile station  $A_1B_1M_{03}$  which is represented by the mobile station position data. When the registry station  $A_1B_1$  decides that the mobile station  $A_1B_1M_{03}$  is currently located at " $A_0B_1C_1D_5$ ", for example, it generates a dynamic vehicle specific code 60 in which the address " $A_0B_1C_1$ " of the district station 30 is included as the running district code 64. The registry station  $A_1B_1$  reads the message out of its memory, adds it to the header of the dynamic code 60, and transmits the dynamic code 60 with such a header to the district station  $A_0B_1C_1$ .

[0053] Transit stations such as the central and regional stations 34 and 32 identify the dynamic vehicle code 60 of the message and transfer it to the district station  $A_0B_1C_1$ . On reception of the message with the header, the district station  $A_0B_1C_1$  accesses all of its subordinate roadside stations 10 at the same time by a send request, the message, and the destination code " $A_1B_1M_{03}$ " to which the message is destined. In response, each roadside station 10 once stores the message in the memory 42 and polls mobile stations 16 which are present in its service zone 20. This polling is effected by using the introductory field 102 of the frame 100, as stated earlier.

[0054] In response to the polling, active mobile stations 16 present in the service zone 20 which is defined by the roadside station 10 generate the vehicle codes 50 and 60 (FIG. 3) by the individual vehicle code generating units 130 and return them to the roadside station 10. This is implemented by the vehicle ID field 104 (FIG. 4) of the frame 100. The roadside station 10 temporarily stores the vehicle codes returned from the mobile stations 16 and compares the individual static vehicle codes 50 with the destination code " $A_1B_1M_{03}$ " (142). When any of the static vehicle codes coincides with the destination code at a certain roadside station 10, that roadside station 10 reads the message out of its memory 42 and sends it over the channel of the mobile station  $A_1B_1M_{03}$  by using the vehicle communication field 108 of the frame 100. The mobile station  $A_1B_1M_{03}$  received the message returns an answer for confirmation to the roadside station 10 by using the end-of-communication field 110 of the frame, the answer being finally transferred to the registry station 32. If the answer includes a positive response ACK, the district station  $A_0B_1C_1$  cancels the send request to the other roadside stations 10.

[0055] The other roadside stations 10 where the coincidence of the two different kinds of codes has not occurred discard the message stored in their memories 42 and end this processing, under the control of the district station  $A_0B_1C_1$ . While the individual stations return a confirmation signal at each step of the sequence described above, such a procedure is not shown in FIG. 9

to avoid intricacy of illustration.

[0056] In summary, in this particular embodiment, the mobile stations 16 are individually registered in particular land stations. A land station detected a mobile station 16 which is registered in a particular land station reports the current position of the station 16 to the latter land station to allow it to store the current position data. The current position data is constantly updated on a real time basis. When a certain mobile station 16 is to receive a call, a registry station where the mobile station 16 is registered is accessed to see the current position of the mobile station 16. The mobile station 16, therefore, is connected to any of the roadside stations 10 which is adjacent to the current position of the mobile station 16.

[0057] To efficiently control the termination of a call at a mobile station 16, a plurality of roadside stations 10 may be constructed into a paging group on the basis of their locations, as described hereinafter. In this alternative illustrative embodiment, a paging is effected by handling the group as a unit. The group configuration may be such that all the roadside stations 10 belonging to a single district station 30 constitute a paging group. Alternatively, some of the roadside stations 10 which are subordinate to the same district station 30 and geographically adjacent to each other may be treated as a paging group. An alternative embodiment of the telecommunications network 22 for implementing the second-mentioned paging group configuration is shown in FIG. 11. In the figure, the district station 30 has a roadside station table 134 which stores which of the roadside stations 10 in the coverage area belong to which paging group. The table 134 is referenced when a paging is to be effected for the termination of a call at a mobile station 16.

[0058] As shown in FIG. 10, when the mobile station  $A_1B_1M_{03}$  is operated on an ordinary road 136 toward a crossroad 138 by way of example, there are three different directions which the mobile station  $A_1B_1M_{03}$  may travel via the crossroad 138. For example, assume that the mobile station  $A_1B_1M_{03}$  is running in the coverage area of the roadside station  $A_0B_1C_1D_5$  and, therefore, the current position " $A_0B_1C_1D_5$ " of the mobile station  $A_1B_1M_{03}$  is stored in the running vehicle table 80 of the registry station  $A_1B_1$ . When the current position " $A_0B_1C_1D_5$ " of the mobile station  $A_1B_1M_{03}$  is determined by referencing the running vehicle table 80 and, based on this position, the mobile station  $A_1B_1M_{03}$  is called via the roadside station  $A_0B_1C_1D_5$ , the termination of the incoming call at the station  $A_1B_1M_{03}$  often fails because the probability that the station  $A_1B_1M_{03}$  has already moved away from the service zone 20 of the roadside station  $D_5$  is great. The route which the mobile station  $A_1B_1M_{03}$  moved away from the service zone 20 may take is indefinite, as shown in the figure.

[0059] To eliminate the above problem, this particular embodiment arranges the roadside stations 10 in a paging group configuration. In the example shown in FIG. 10, the roadside stations  $D_2$ ,  $D_3$ ,  $D_4$ ,  $D_5$  and  $D_6$  which

geographically adjoin each other around the road 136 are accommodated in a single district station 30 to constitute a single paging group. This group is listed in the roadside station table 134 of the district station  $A_0B_1C_1$ . If desired, only the roadside stations  $D_3$ ,  $D_4$  and  $D_6$  may be constructed into a group.

[0060] Again, a reference will be made to FIG. 9 for describing a sequence available with this particular embodiment to terminate a call from the center 26 or 28 at a mobile station  $A_1B_1M_{03}$  on the basis of the mobile station position data which is constantly updated at the registry station  $A_1B_1$ . As stated previously, a message to be sent from the center 26 or 28 to the mobile station  $A_1B_1M_{03}$  is transmitted to the registry station  $A_1B_1$  via the central station 34, together with a header in the form of the static vehicle code 50 which includes the destination code " $A_1B_1M_{03}$ ". For so transferring the message, the transit stations individually identifies the destination code " $A_1B_1M_{03}$ " of the message. On reception of the message with the header, the registry station  $A_1B_1$  checks the destination code to see if the mobile station  $A_1B_1M_{03}$  is a registered or qualified station and, if it is qualified, temporarily stores the message in a memory (not shown) (140). At this instant, the station  $A_1B_1$  returns a confirmation signal to the center 26 or 28, although not shown in the figure.

[0061] Then, the registry station  $A_1B_1$  references the running vehicle table 80 to determine the current position of the mobile station  $A_1B_1M_{03}$  on the basis of the mobile station position data being stored in the table 80. In the illustrative embodiment, if the current position is " $A_0B_1C_1D_5$ " by way of example as determined by the registry station  $A_1B_1$ , the registry station  $A_1B_1$  produces a dynamic vehicle specific code 60 which includes the address " $A_0B_1C_1D_5$ " of the roadside station 10 as the running area code 64 (FIG. 3). The registry station  $A_1B_1$  reads the message out of the memory, adds the dynamic code 60 to the header of the message, and transmits the resulting message and header to the district station  $A_0B_1C_1$ .

[0062] Transit stations such as the central and regional stations 34 and 32 individually identify the dynamic vehicle code 60 of the message and transfer it to the district station  $A_0B_1C_1$ . On reception of the message and header, the district station  $A_0B_1C_1$  identifies the roadside station 10 which is represented by the running area code 64 of the header and, based on the identified roadside station 10, references the roadside station table 134. In this example, since the roadside station code is representative of " $D_5$ ", the district station  $A_0B_1C_1$  determines that the paging group made up of the roadside stations  $D_3$ ,  $D_4$  and  $D_6$  is the group to be accessed. Then, the district station  $A_0B_1C_1$  determines the running direction of the mobile station  $A_1B_1M_{03}$  and accesses all of the roadside stations  $D_3$ ,  $D_4$  and  $D_6$  at the same time. The rest of the call termination sequence is the same as the previous embodiment.

[0063] As described above, in this particular embodi-

ment, the roadside stations 10 which are geometrically associated with other are arranged in a paging group configuration. To terminate a call at any of the mobile stations 16, the current position of the mobile station 16 is determined by accessing a registry station where the mobile station 16 is registered and, then, the roadside stations 10 belonging to a single group associated with or estimated from the determined current position access the desired mobile station 16 at the same time. This eliminates the problem ascribable to the uncertainty of the position of the mobile station 16 and thereby promotes efficient call termination control.

[0064] In the case that a single district station 30 covers a single paging group, the current position data supplied in the event of call termination does not have to include a roadside station code and, further, the district station 30 does not have to have the roadside station table 134. In this case, the district station 30 will access all of the roadside stations 10 lying in its coverage area in response to an incoming call.

[0065] Hereinafter will be described an alternative embodiment of the present invention in which information indicative of whether or not a mobile station 16 is running past a roadside station 10 located at the end of the coverage area of a district station 30 is supplied, so that the movement of the mobile station 16 may be estimated with accuracy to implement efficient call termination control. FIG. 12 shows a specific format of the vehicle code which is applicable to this embodiment. In the figure, the current position data associated with the mobile station 16 includes the land station code " $A_0B_1C_1$ " and a boundary bit 64a, which has to be understood as the second position information (64a) in the following indicative of whether or not a mobile station (16) is located at an outgoing end of an area, in the form of the running area code 64 of the dynamic vehicle code 60.

[0066] The boundary bit 64a shows whether or not the roadside station 10 detected the mobile station 16 is located at the end of the coverage area of the district station 30. As shown in FIG. 13, assume that the roadside stations  $D_0$  to  $D_7$  belonging to the district station  $A_0B_1C_1$  are arranged linearly along a single road 136 such as a thruway, and that the roadside station  $D_7$  which adjoins another district station  $A_0B_1C_2$  at the end of the coverage area of the district station  $A_0B_1C_1$  has detected the mobile station 16. Then, the district station  $A_0B_1C_1$  sets a significant bit such as a (logical) ONE in the boundary bit 64a. For this purpose, in this particular embodiment, the district station 30 has the roadside station table 134 (FIG. 11) that stores which of the roadside stations 10 belonging to its own coverage area adjoins another district station 30, i. e., which of such roadside stations 10 are the "end stations" in the limited coverage area. In the example shown in FIG. 13, the roadside station  $A_0B_1C_1D_7$  is listed in the roadside station table 134 as "outgoing end station" with respect to the running direction of the vehicle 12. While a single outgoing end station

is shown in this example, two or more outgoing end stations may exist in the case of actual roads which are developed two-dimensionally.

**[0067]** As shown in FIG. 14, which is an example of an illustrative embodiment of the present invention, when the roadside station  $A_0B_1C_1D_5$  detects the mobile station  $A_1B_1M_{03}$  (150), the district station  $A_0B_1C_1$  determines that the roadside station  $A_0B_1C_1D_5$  is not the outgoing end station by referencing the roadside station table 134 (151). In this condition, the district station  $A_0B_1C_1$  sends the running area code 64 and dynamic vehicle code 50 (154) while maintaining a (logical) ZERO in the boundary bit 64a (152). When the roadside station  $A_0B_1C_1D_7$  detects the mobile station  $A_1B_1M_{03}$ , the district station  $A_0B_1C_1$  sees that the roadside station  $A_0B_1C_1D_7$  is the outgoing end station by referencing the roadside station table 134. Then, the district station  $A_0B_1C_1$  turns the boundary bit 64a from ZERO to ONE (153) and transmits the mobile station data 50 and 60 (154).

**[0068]** Switching stations lying above the district station  $A_0B_1C_1$  such as the regional station  $A_0B_1$  and central stations  $A_0$  and  $A_1$  identify the destination of the mobile station position data on the basis of the vehicle code " $A_1B_1M_{03}$ " and repeat it to the registry station in which the mobile station  $A_1B_1M_{03}$  is registered, i. e. the regional station  $A_1B_1$  in this example. On reception of the mobile station position data, i. e., the static vehicle code 50 and dynamic vehicle code 60, the registry station  $A_1B_1$  identifies the mobile station 16 of interest, i. e., the station  $M_{03}$  in this example on the basis of the mobile station code 54 and stores such position data in the associated location of the running vehicle table 80. These position data, of course, include the boundary bit 64a.

**[0069]** Again, a reference will be made to FIG. 9 for describing a sequence available with this particular embodiment to terminate a call from the center 26 or 28 to the mobile station  $A_1B_1M_{03}$  on the basis of the mobile station position data which is constantly updated at the registry station  $A_1B_1$ . A message to be sent from the center 26 or 28 to the mobile station  $A_1B_1M_{03}$  is transmitted to the registry station  $A_1B_1$  via the central station 34, together with a header in the form of the static vehicle code 50 which includes a destination code " $A_1B_1M_{03}$ ". For so transferring the message, the transmit stations individually identifies the destination code " $A_1B_1M_{03}$ " of the message. On reception of the message with the header, the station  $A_1B_1$  checks the destination code to see if the mobile station  $A_1B_1M_{03}$  is a registered or qualified station and, if it is qualified, temporarily stores the message in a memory (not shown) (140). At this instant, the registry station  $A_1B_1$  returns a confirmation signal to the center 26 or 28, although not shown in the figure.

**[0070]** The registry station  $A_1B_1$  checks the running vehicle table 80 (160, FIG. 15) to determine the current position of the mobile station  $A_1B_1M_{03}$  of interest as indicated by the mobile station position data. If a ONE is

not set in the boundary bit 64a associated with the mobile station  $A_1B_1M_{03}$  (161), the registry station  $A_1B_1$  prepares, on the basis of the current position such as " $A_0B_1C_1$ ", a dynamic vehicle code 60 which includes the running area code in the form of the address " $A_0B_1C_1$ " of the district station 30 (162). The registry station  $A_1B_1$  reads the message out of the memory, adds the dynamic code 60 to the header, and sends the resulting header and message to the district station  $A_0B_1C_1$  (163).

**[0071]** Transit stations such as the central station 34 and regional station 32 identify the dynamic vehicle code 60 of the message and transfer it to the district station  $A_0B_1C_1$ . As the district station  $A_0B_1C_1$  receives the message together with the header, it accesses all of its associated roadside stations 10 at the same time.

**[0072]** Referring again to FIG. 15, if the boundary bit 64a is a ONE as determined in the step 161 by the registry station  $A_1B_1$ , in the illustrative embodiment, the transmission of the message is not effected until position data having a ZERO in the boundary bit 64a has been received afterwards with respect to the mobile station  $A_1B_1M_{03}$  (164). This is because, even if call termination at the mobile station  $A_1B_1M_{03}$  is attempted via the district station  $A_0B_1C_1$ , the probability that the mobile station  $A_1B_1M_{03}$  seizes it is generally small. In this manner, this embodiment allows a minimum of ineffective termination of a call at the mobile station 16 to occur by giving special significance to the outgoing end station which is present in the coverage area of the district station 30.

**[0073]** If desired, in the step 164 where the registry station  $A_1B_1$  is in a waiting condition, whether or not new position data arrives within a predetermined period of time may be determined. If the predetermined period of time expires before the arrival of new position data, the district station  $A_0B_1C_1$  stored in the running vehicle table 30 will access the mobile station  $A_1B_1M_{03}$  by paging.

**[0074]** An alternative illustrative embodiment will be described which is so constructed as to effect a paging to a mobile station which is running at the incoming end of the coverage area of an adjoining district station 30 also. One of characteristic features of this embodiment is that particular ones of the roadside stations 10 are subordinate not only to their associated district stations 30 but also to other district stations 30, as indicated by dotted lines 180 in FIG. 16. Specifically, assuming that the roadside station  $D_7$  geographically belonging to the coverage area of a certain district station  $C_1$  and accommodated in the latter is located in close proximity to the coverage area of another district station  $C_2$ , i. e., the roadside station  $D_7$  is an "end station", the roadside station  $D_7$  is also connected to the district station  $C_2$  such that it is logically subordinate to the district station  $C_2$  as to the control over call termination at the mobile station 16 and is controlled by the latter as well.

**[0075]** For example, the district station  $C_1$  accommodates the roadside stations  $D_0$  to  $D_7$  so that when any of the subordinate roadside stations  $D_0$  to  $D_7$  detects

the mobile station 16, the district station  $C_1$  is informed of the detection from that roadside station as usual. However, in response to an incoming call meant for the mobile station 16, the district station  $C_1$  simultaneously accesses not only its own roadside stations  $D_0$  to  $D_7$  but also a roadside station of the adjacent area, e. g., a roadside station  $A_0B_1C_2D_0$  which is located at the incoming end of the adjacent district station  $C_2$ . That the call termination control extends from the district station 30 located in a certain region to a roadside station 10 located in the adjacent region is represented by the dotted lines 180 in FIG. 16. In the example shown in FIG. 16, the roadside station  $D_7$  associated with the district station  $C_1$  is also an incoming end station when it comes to the vehicle 12 which moves away from the district station  $C_2$  to the district station  $C_1$  and, therefore, it is subordinate to the district station  $C_2$  with respect to call termination control. It is to be noted that two or more incoming end stations may exist in the case of an actual road because the roadside stations 10 associated with such a road are usually developed two-dimensionally.

**[0076]** Concerning the roadside station  $D_7$  located at the end of the coverage area of the district station  $C_1$ , the land station code may include the boundary bit (FIG. 12) indicative of the fact that the coverage area terminates at the station  $D_7$  when the station  $D_7$  has detected the mobile station  $A_1B_1M_{03}$ , as in the previous embodiment. Further, an arrangement may be made such that when a certain district station 30 has detected the mobile station  $M_{03}$  for the first time via any of its subordinate roadside stations 10, it reports the detection to the registry station  $A_1B_1$  where the mobile station  $M_{03}$  is registered.

**[0077]** It rarely occurs that the mobile station  $M_{03}$  detected by the outgoing end station  $A_0B_1C_1D_7$  remains in the coverage area of the same district station  $C_1$ . Hence, as shown in FIG. 17A, if the system architecture is such that each of the end stations  $C_1D_7$  and  $C_2D_0$  is subordinate solely to its associated district station  $C_1$  or  $C_2$ , the termination of an incoming call from the district station  $C_1$  at the mobile station  $M_{03}$  which may be attempted after the outgoing end station  $C_1D_7$  has detected the mobile station  $M_{03}$  will in many cases be unsuccessful. Generally, it is only after the incoming end station  $C_2D_0$  of the adjoining district station  $C_2$  has detected the mobile station  $M_{03}$  and reported its current position to the registry station  $A_1B_1$  that a call termination is attempted via the district station  $C_2$ . Therefore, the mobile station  $M_{03}$  cannot receive a call until, at the earliest, it reaches the zone 20 of the next roadside station  $C_2D_1$ , resulting in a substantial delay in the termination of a call. In FIG. 17A, the locations where a call can be received are indicated by bold arrows 16 while the roadside stations associated with such locations are indicated by hatching.

**[0078]** In contrast, in the illustrative embodiment, the architecture is such that the incoming end station  $C_2D_0$  of the district station  $C_2$  which adjoins the district station

$C_1$  is logically subordinate to the district station  $C_1$  as well, as shown in FIG. 17B. In this construction, even when the mobile station  $M_{03}$  enters the coverage area of the district station  $C_2$  after the outgoing end station  $C_1D_7$  of the district station  $C_1$  has detected it, the probability of a call being successfully terminated at the mobile station  $M_{03}$  is great because the district station  $C_1$  accesses not only its coverage area but also the incoming end station  $C_2D_0$  of the adjoining district at the same time.

**[0079]** In the example shown in FIG. 17, incoming and outgoing end stations 10 are shown as being subordinate with respect to opposite directions of travel of a vehicle, i. e., the end station  $C_1D_7$  of the district station  $C_1$  which adjoins the district station  $C_2$  is subordinate to the district station  $C_2$  also. This allows even the mobile station 16 running in the opposite direction from the district station  $C_2$  to the district station  $C_1$  to receive a call efficiently. However, such a both-direction double-subordinate scheme is not essential. For example, when the distance between two nearby roadside stations 10 is relatively short, the end station 10 may be subordinate to the two nearby district stations  $C_1$  and  $C_2$  with respect to one direction only, as shown in FIG. 17C. In the example shown in FIG. 17C, since the distance between the roadside stations  $C_1D_6$  and  $C_1D_7$  belonging to the district station  $C_1$  is shorter than the distance between the others, an arrangement is made such that the station  $C_1D_7$  is subordinate solely to the district station  $C_1$  as to a mobile station running in the opposite direction to the mobile station  $M_{03}$  such as  $M_{04}$ . Although the arrangement shown in FIG. 17 allows the mobile station  $M_{04}$  to receive a call only when the latter enters the service zone of the roadside station  $C_1D_6$ , the distance between the roadside station  $C_1D_6$  and the incoming end station  $C_1D_7$  is sufficiently short to prevent the serviceability from being critically degraded.

**[0080]** In this particular embodiment, when the district station 30 accesses its own roadside stations 10 at the same time for the termination of a call at the mobile station 16, it necessarily accesses the incoming end station 10 of the adjoining district also. It is not necessary, however, that the roadside station 10 of the adjoining district station be accessed as stated. For example, in the case that the current position of the motor vehicle 16 is detected with a boundary included in the running area code 64 as discussed earlier, the call termination control may be such that the incoming end station 10 of the adjoining district is accessed by paging only when the boundary bit shows that the mobile station 10 has been detected by the end station 10.

**[0081]** In summary, in this particular embodiment, a call is terminated at the mobile station by causing the district station 30 to access not only its own roadside stations 10 but also the incoming end station 10 of the adjoining district station 30 at the same time. This reduces the chance of ineffective paging for call termination and thereby enhances efficient call termination con-

trol.

[0082] An alternative illustrative embodiment will be described which is constructed such that, when a mobile station 16 leaves a certain district station 30, an area which the mobile station 16 will enter next is estimated to cause a district station 30 covering that area to terminate an incoming call. A specific system construction of this embodiment is shown in FIG. 18, while the hierarchy of the telecommunications network 22 is shown in FIG. 19. In the example shown in FIG. 13, the mobile station  $A_1B_1M_{03}$  running on the road 136 away from the end station  $A_0B_1C_1D_7$  will soon enter the coverage area of the adjoining district station  $A_0B_1C_2$ . In another example shown in FIG. 21, the mobile station  $A_1B_1M_{03}$  running on the road 136 away the end station 10 of the district station  $A_0B_1C_1$  will soon reach either one of district stations  $A_0B_1C_2$  and  $A_1B_0C_0$ .

[0083] In this particular embodiment, such a possibility of travel of the mobile station 16 over adjoining district stations 30 is stored in the form of a district station table 138 of the present invention (FIG. 18) in the memory of the registry station, e. g. the regional station  $A_1B_1$ . More specifically, the district station table of the registry station  $A_1B_1$ , for example, lists for each of the district stations 30 which belong to the network 22 the adjoining district stations 30 to which the mobile station 16 moving away from the coverage area of the district station 30 is likely to enter next. To terminate a call to the mobile station, the district station table 138 (FIG. 19) is referenced so that any adjoining district station 30 to which the mobile station 16 is likely to move is selected, as described in detail later.

[0084] In this embodiment, the information indicative of the current position of the mobile station 16 is implemented as the own station position information. The position information includes the land station code " $A_0B_1C_1$ " and boundary bit (FIG. 12) in the form of the running area code 64 of the dynamic vehicle code 60.

[0085] A sequence for terminating a call from the center 26 or 28 at the mobile station  $A_1B_1M_{03}$  by using the mobile station position data which is constantly updated by the registry station  $A_1B_1$  will be described with reference to FIG. 9, as in the previous illustrative embodiments. A message from the center 26 or 28 and meant for the mobile station  $A_1B_1M_{03}$  is sent to the registry station  $A_1B_1$  via the central station 34 together with a header in the form of the static vehicle code 50 which includes a destination code " $A_1B_1M_{03}$ ". This message transfer is effected by causing each transmit station to identify the destination code " $A_1B_1M_{03}$ " of the message. On reception of the message together with the header, the registry station  $A_1B_1$  checks the mobile station  $A_1B_1M_{03}$  as to qualification on the basis of the destination code and, if it is qualified, temporarily stores the message in its memory (not shown) (140). In this instance, the registry station  $A_1B_1$  returns a confirmation signal to the center 26 or 28.

[0086] By referencing the running vehicle table 80

(220, FIG. 20), the registry station  $A_1B_1$  determines the current position of the mobile station  $A_1B_1M_{03}$  on the basis of the listed position data. If a ONE which is a significant bit is not set in the boundary bit 64a (FIG. 12) of the mobile station  $A_1B_1M_{03}$  (222), the registry station  $A_1B_1$  produces a dynamic vehicle code 60 which includes a running area code 64 from the current position of the mobile station  $A_1B_1M_{03}$ , e. g. a running area code " $A_0B_1C_1$ " from the current position " $A_0B_1C_1$ ". Then, the registry station  $A_1B_1$  reads the message out of the memory, adds the dynamic code 60 to the header of the message, and sends the resulting header and message to the district station  $A_0B_1C_1$  (226). In response, the district station accesses all of its subordinate road stations 10 simultaneously.

[0087] Turning back to FIG. 20, if the boundary bit 64a is a ONE as determined in the step 161 by the registry station  $A_1B_1$ , the station  $A_1B_1$  references the district station table with respect to the district station code " $A_0B_1C_1$ " and thereby produces a district station which governs the district which the mobile station 16 is expected to enter next (228). In the example of the present invention shown in FIG. 13, the mobile station  $A_1B_1M_{03}$  running on the road 136 away from the end station  $A_0B_1C_1D_7$  will enter the coverage area of the district station  $A_0B_1C_2$  in due course. In this case, the registry station  $A_1B_1$  produces the district station  $A_0B_1C_2$  out of the table 138. On the other hand, in the example of the present invention of FIG. 21, the mobile station  $A_1B_1M_{03}$  running on the road 136 away from the district station  $A_0B_0C_1$  will soon reach either one of the district stations  $A_0B_1C_2$  and  $A_1B_0C_0$ . Then, the registry station  $A_1B_1$  produces the district station  $A_0B_1C_2$  and  $A_1B_0C_0$ .

[0088] By using the produced district station code for an address (230), the station  $A_1B_1$  transmits a message and terminate a call in the previously described manner (226). When a plurality of district addresses are produced as stated above, the station  $A_1B_1$  accesses all of them at the same time or, alternatively, one after another according to a predetermined priority order. The priority order may be set beforehand on a district station basis or may be selected randomly.

[0089] The estimation of a district station discussed above is effective in reducing the possibility that when a call termination at the mobile station  $A_1B_1M_{03}$  is attempted via the district station  $A_0B_1C_1$  which is indicated by the current position information, the mobile station fails to seize the call, whereby the frequency of retry is lowered. Thus, this embodiment allows a minimum of wasteful termination of a call at the mobile station 16 to occur by giving special significance to the end stations subordinate to each district station 30.

[0090] While adjoining district stations 30 have been shown and described as being searched by the registry station, this kind of search is not necessary and, of course, may be assigned to a station other than the registry station. For example, either the central station 34 or the regional station 32 may be provided with a similar

district station table so as to perform the search in response to a message which is destined to the mobile station 16. Further, the search of adjoining districts may be assigned to the regional stations in place of the district stations.

**[0091]** An alternative approach for the detection of the travelling position of the mobile station 16 in accordance with the present invention will be described. In this embodiment, as shown in FIG. 3, an ID code designating a mobile station 16, i. e., a vehicle specific code is constituted by a static code 50 and a dynamic code 60. As shown in FIGS. 22 and 23, the memory of each district station 30 stores a passing vehicle table 170. This table 170 lists data associated with the mobile stations 16 which are detected in the service zones 20 of all of the roadside stations that are accommodated in the district station 30. In the illustrative embodiment, it is only when the district station 30 has found a new or strange mobile station 16 in its coverage area that it holds a communication with the registry station where that mobile station 16 is registered for informing the latter of the current position of the mobile station 16. This alleviates the communication traffic needed for reporting the current position and simplifies the processing which the registry station has to execute for managing the running positions. The passing vehicle table 170 is referenced in order to determine whether or not a mobile station 16 seized by any roadside station 10 is a newcomer in the coverage area of the district station 30. Also, when the roadside stations 10 are not arranged in a paging group configuration as to an incoming call, the table 170 is used to search for a roadside station 10 which can terminate a call at the mobile station 16.

**[0092]** For example, as shown in FIG. 22, assume that one  $C_1$  of multiple district stations subordinate to a regional station  $A_0B_1$  accommodates eight roadside stations 10 which are designated respectively by station codes  $D_0$  to  $D_7$ . In the figure, the sixth roadside station 10 as counted from the left is designated by a station code " $A_0B_1C_1D_5$ ". When a mobile station 16 having a static vehicle code 50 of " $A_1B_1M_{03}$ " is polled by the roadside station  $A_0B_1C_1D_5$  while running within the zone 20 of the latter, it returns an ID code " $A_1B_1M_{03}$ " to the roadside station as a land station code 52 and a mobile station code 54.

**[0093]** The roadside station 10 may store in the passing vehicle table 82 the data which are associated with the subscriber vehicles 12 and obtained from the mobile stations 16 present in the zone 20 at each polling period. The roadside station 10 transfers such data to the associated district station 30 over the channel 36. In this embodiment, the district station 30 is so constructed as to inform the registry station  $A_1B_1$  of the current position of a particular mobile station such as  $A_1B_1M_{03}$  for the first time when it has detected the mobile station through any of its associated roadside stations 10

**[0094]** As shown in FIG. 13, assume that the mobile station  $A_1B_1M_{03}$  running on the road 136 has moved

away from the end roadside station  $A_0B_1C_1D_7$  subordinate to the district station  $A_0B_1C_1$  into the zone 20 which is defined by the first roadside station  $A_0B_1C_2D_0$  subordinate to an adjoining district station  $A_0B_1C_2$ . Then, the roadside station  $A_0B_1C_2D_0$  reports the vehicle code 50 of the mobile station  $A_1B_1M_{03}$  to its associated district station  $A_0B_1C_2$  which in turn stores it in its passing vehicle table 170. At this instant, the district station  $A_0B_1C_2$  checks the table 170 to see if the vehicle code " $A_1B_1M_{03}$ " has been listed in the past (172, FIG. 24). If it has not been listed, the district station  $A_0B_1C_2$  transfers the current position data of the mobile station  $A_1B_1M_{03}$  to the registry station  $A_1B_1$  via its associated district station  $A_0B_1$ . In this case, the station code " $A_0B_1C_2$ " sufficiently implements the current position data.

**[0095]** More specifically, as shown in FIG. 23, each district station 30 has a station code generating unit 132 for generating a land station code 52 which designates the station 30 itself. Concerning the district station  $A_0B_1C_2$ , for example, the station code generating unit 132 is loaded with a code " $A_0B_1C_2$ " as the land station code 52. The vehicle code " $A_1B_1M_{03}$ " of the mobile station 16 received by the roadside station  $A_0B_1C_2D_0$  is once stored in the passing vehicle table 82 of the roadside station 10 while being transferred to the associated district station  $A_0B_1C_2$ .

**[0096]** As the district station  $A_0B_1C_2$  decides that the vehicle code " $A_1B_1M_{03}$ " has not been stored in the passing vehicle table 170 (172), it determines that the mobile station  $A_1B_1M_{03}$  is registered in the regional station  $A_1B_1$  which belongs to the central station  $A_1$  on the basis of the vehicle code " $A_1B_1M_{03}$ " and, then, transfers the vehicle code " $A_1B_1M_{03}$ " to the station  $A_1B_1$ , as shown in FIG. 24. At this instant, the district station  $A_0B_1C_2$  sends its own position information for indicating the current position of the mobile station 16. This position information includes the land station code " $A_0B_1C_2$ " in the form of the running area code 64 of the dynamic vehicle code 60.

**[0097]** Switching stations lying above the district station  $A_0B_1C_2$  such as the regional station  $A_0B_1$  and central stations  $A_0$  and  $A_1$  individually repeat the mobile station position data toward the registry station, i. e., the regional station  $A_1B_1$  in this example while identifying the destination on the basis of the vehicle code " $A_1B_1M_{03}$ ". On receiving the mobile station position, i. e., the static vehicle code 50 and dynamic vehicle code 60, the registry station  $A_1B_1$  identifies the mobile station 16 of interest, i. e., the mobile station  $M_{03}$  in this example on the basis of the mobile station code 54 and writes these position data in a predetermined location of the running vehicle table 80. In this manner, the running vehicle table 80 of the registry station  $A_1B_1$  is constantly updated by incoming new data. In this system, a communication for reporting the current position occurs only when a new mobile station 16 is found in the coverage area of the district station 30, so that the communication

traffic is alleviated and the processing to be executed by the registry station for dealing with the running positions is simplified.

[0098] The current position data associated with each mobile station 16 is constantly updated. Concerning the mobile station  $M_{03}$ , for example, when any of the district stations 30 detects it through its subordinate roadside station 10 for the first time, the district station 30 informs the registry station  $A_1B_1$  of the presence of the mobile station  $M_{03}$ . Hence, the data listed in the running vehicle table 80 is updated as to the mobile station  $M_{03}$ .

[0099] It is to be noted that a particular mobile station 16 is not always detected for the first time through a roadside station 10 which is located at the end of the coverage area of a district station 30. Specifically, it may occur that the district station 30 finds the mobile station 16 for the first time through its subordinate roadside station 10 other than the end station 10, e. g., when the vehicle 12 moves into the coverage area of another district station 30 with the power supply of the on-board unit 16 being turned off and then the power supply is turned on.

[0100] To summarize this embodiment, each mobile station 16 is registered in a particular land station beforehand. When a district station 30 detects a particular mobile station 16 for the first time through any of its subordinate roadside stations 10, it informs the registry station of the current position of the mobile station 16. The registry station in turn holds the current position data and constantly updates it on a real time basis. Since it is only when the district station 30 has detected the mobile station 16 through the subordinate roadside station 10 that it reports the current position of the mobile station 16 to the registry station, the communication traffic for reporting the current position is minimized and therefore prevented from interfering with the data communication traffic which is the primary traffic.

## Claims

### 1. A mobile telecommunications system comprising:

a mobile station (16);  
a plurality of base stations (10) each communicable with said mobile station (16) over a radio link, said plurality of base stations (10) having service zones (20) that are spaced apart from each other by an area in which the mobile station is substantially not responsive to an electromagnetic wave on the radio link, and being allowed to share a single frequency of the electromagnetic wave; and  
a communication network (22) interconnected to said plurality of base stations (10) and constituted by a plurality of switching stations (30, 32, 34) for switching a call to and from said plurality of base stations (10) in accordance with

an identification code designating said mobile station (16) and position information of said mobile station (16), wherein

in a first one of said plurality of switching stations (30, 32, 34), said mobile station (16) is registered in association with the identification code,

said switching stations (30, 32, 34) being arranged to receive the identification code from said mobile station (16), to add information associated with a position of said mobile station (16) to said identification code to form the position information of said mobile station (16) and to transfer the position information to said first switching station,

said first switching station being arranged to store the position information in association with the identification code to update the stored position information,

### characterized in that

said communication network (22) comprises a table (138) defining how each of said plurality of switching stations (30) is adjacent to ones of said plurality of switching stations (30), with reference to their coverage areas,

associated ones of said plurality of base stations (10) with respect to an area form a group and are interconnected to a second one of said plurality of switching stations (30),

the position information comprises first position information (64) representative of a position of said mobile station (16) and second position information (64a) indicative of whether or not said mobile station (16) is located at an outgoing end of the coverage area of a switching station,

each of said plurality of switching stations (30, 32, 34) is arranged to transfer, when one of said plurality of base stations (10) to which the switching station is interconnected detects said mobile station (16), the first position information (64) and the second position information (64a) to said first switching station (30, 32, 34);

said first switching station is adapted to reference, when an incoming call is to be terminated at said mobile station (16), the first and second position information (64, 64a), and to cause, if the second position information (64a) shows that said mobile station (16) is not located at the outgoing end of the coverage area, the call to be terminated at said mobile station (16) from said switching station (30) associated with the first position information (64), and to reference, if the second position information (64a) shows that said mobile station (16) is located at the outgoing end of the coverage area, the table (138) to produce an indication of ones of said switching stations (30) which are adjacent to said switching station (30) associated with the first

position information (64), make an access to the switching stations (30) thus indicated and cause the call to be terminated at said mobile station (16) via one of the switching stations (30) thus indicated.

## Patentansprüche

### 1. System für die mobile Telekommunikation, das umfaßt:

eine Mobilstation (16) ;  
mehrere Basisstationen (10), die jeweils mit der Mobilstation (16) über eine Funkverbindung kommunizieren können, wobei die mehreren Basisstationen (10) Dienstzonen (20) besitzen, die voneinander durch einen Bereich beabstandet sind, in dem die Mobilstation im wesentlichen nicht auf eine elektromagnetische Welle auf der Funkverbindung antwortet, und die eine einzige Frequenz der elektromagnetischen Welle gemeinsam nutzen dürfen; und ein Kommunikationsnetz (22), das mit den mehreren Basisstationen (10) verbunden und durch mehrere Vermittlungsstationen (30, 32, 34) gebildet ist, die einen Anruf an die bzw. von den mehreren Basisstationen (10) entsprechend einem Identifizierungscode, der die Mobilstation (16) bezeichnet, und entsprechend Positionsinformationen der Mobilstation (16) vermitteln, wobei in einer ersten der mehreren Vermittlungsstationen (30, 32, 34) die Mobilstation (16) in Zuordnung zu dem Identifizierungscode registriert ist, die Vermittlungsstationen (30, 32, 34) so beschaffen sind, daß sie den Identifizierungscode von der Mobilstation (16) empfangen, um einer Position der Mobilstation (16) zugeordnete Informationen zu dem Identifizierungscode hinzuzufügen, um die Positionsinformationen der Mobilstation (16) zu bilden und sie an die erste Vermittlungsstation zu übertragen, die erste Vermittlungsstation so beschaffen ist, daß sie die Positionsinformationen in Zuordnung zu dem Identifizierungscode speichert, um die gespeicherten Positionsinformationen zu aktualisieren,

**dadurch gekennzeichnet, daß**

das Kommunikationsnetz (22) eine Tabelle (138) umfaßt, die unter Bezugnahme auf die Abdeckungsbereiche jeder der mehreren Vermittlungsstationen (30) definiert, wie jede dieser mehreren Vermittlungsstationen (30) an einige der mehreren Vermittlungsstationen (30) angrenzt,

einige der mehreren Basisstationen (10), die einander in bezug auf einen Bereich zugeordnet

sind, eine Gruppe bilden und mit einer zweiten der mehreren Vermittlungsstationen (30) verbunden sind,

die Positionsinformationen erste Positionsinformationen (64), die eine Position der Mobilstation (16) repräsentieren, und zweite Positionsinformationen (64a), die angeben, ob sich die Mobilstation (16) an einem Ausgangsende des Abdeckungsereichs einer Vermittlungsstation befindet, umfassen,

jede der mehreren Vermittlungsstationen (30, 32, 34) so beschaffen ist, daß sie dann, wenn eine der mehreren Basisstationen (10), mit der die Vermittlungsstation verbunden ist, die Mobilstation (16) erfaßt, die ersten Positionsinformationen (64) und die zweiten Positionsinformationen (64a) an die erste Vermittlungsstation (30, 32, 34) überträgt,

die erste Vermittlungsstation so beschaffen ist, daß sie dann, wenn ein ankommender Anruf an die Mobilstation (16) gerichtet ist, auf die ersten und zweiten Positionsinformationen (64, 64a) Bezug nimmt und dann, wenn die zweiten Positionsinformationen (64a) zeigen, daß sich die Mobilstation (16) nicht am Ausgangsende des Abdeckungsbereichs befindet, veranlassen, daß der Anruf von der Vermittlungsstation (30), der die ersten Positionsinformationen (64) zugeordnet sind, an die Mobilstation (16) gerichtet wird, und dann, wenn die zweiten Positionsinformationen (64a) zeigen, daß sich die Mobilstation (16) am Ausgangsende des Abdeckungsbereichs befindet, auf die Tabelle (138) Bezug nimmt, um einen Hinweis auf diejenigen der Vermittlungsstationen (30) zu erzeugen, die an die Vermittlungsstation (30) angrenzen, der die ersten Positionsinformationen (64) zugeordnet sind, einen Zugriff auf die somit angegebenen Vermittlungsstationen (30) vornimmt und veranlaßt, daß der Anruf über eine der somit angegebenen Vermittlungsstationen (30) an die Mobilstation (16) gerichtet wird.

## Revendications

### 1. Système de télécommunications mobiles, comprenant :

une station mobile (16) ;  
une pluralité de stations de base (10) pouvant chacune communiquer avec ladite station mobile (16) par l'intermédiaire d'une liaison radio, ladite pluralité de stations de base (10) ayant des zones de desserte (20) qui sont mutuellement espacées par un domaine dans lequel la station mobile n'est pratiquement pas sensible à une onde électromagnétique sur la liaison radio, et étant autorisées à partager une fréquence unique de l'onde électromagnétique ; et un réseau de communication (22) interconnec-

té à ladite pluralité de stations de base (10) et  
 constitué d'une pluralité de stations de commu-  
 tation (30, 32, 34) pour commuter un appel vers  
 et en provenance de ladite pluralité de stations  
 de base (10) en conformité avec un code 5  
 d'identification désignant ladite station mobile  
 (16) et avec des informations de position de la-  
 dite station mobile (16), dans lequel  
 dans une première de ladite pluralité de sta-  
 tions de commutation (30, 32, 34), ladite station 10  
 mobile (16) est enregistrée en association avec  
 le code d'identification,  
 lesdites stations de commutation (30, 32, 34)  
 étant aptes à recevoir le code d'identification de  
 ladite station mobile (16), à ajouter des infor- 15  
 mations associées à une position de ladite sta-  
 tion mobile (16) audit code d'identification pour  
 former les informations de position de ladite  
 station mobile (16) et transférer les informa-  
 tions de position à ladite première station de 20  
 commutation ;  
 ladite première station de commutation étant  
 apte à stocker les informations de position en  
 association avec le code d'identification pour  
 mettre à jour les informations de position stoc- 25  
 kées,

#### caractérisé en ce que

ledit réseau de communication (22) com-  
 prend une table (138) définissant la façon dont cha- 30  
 cune de ladite pluralité de stations de commutation  
 (30) est adjacente à certaines de ladite pluralité de  
 stations de commutation (30) en référence à leurs  
 domaines de couverture,

celles qui sont associées de ladite pluralité de 35  
 stations de base (10) vis-à-vis d'un domaine for-  
 ment un groupe et sont interconnectées à une se-  
 conde de ladite pluralité de stations de commuta-  
 tion (30),

les informations de position comprennent une 40  
 première information de position (64) représenta-  
 tive d'une position de ladite station mobile (16) et une  
 seconde information de position (64a) indiquant si  
 oui ou non ladite station mobile (16) se trouve à une 45  
 extrémité sortante du domaine de couverture d'une  
 station de commutation,

chacune de ladite pluralité de stations de  
 commutation (30, 32, 34) est apte à transférer, lors-  
 que l'une de ladite pluralité de stations de base (10)  
 à laquelle la station de commutation est intercon- 50  
 nectée détecte ladite station mobile (16), la premiè-  
 re information de position (64) et la seconde infor-  
 mation de position (64a) à ladite première station  
 de commutation (30, 32, 34) ;

ladite première station de commutation est 55  
 apte à faire référence, lorsqu'un appel entrant doit  
 être interrompu au niveau de ladite station mobile  
 (16), aux première et seconde informations de po-

sition (64, 64a), et à faire en sorte que si la seconde  
 information de position (64a) montre que ladite sta-  
 tion mobile (16) ne se trouve pas à l'extrémité sor-  
 tante du domaine de couverture, l'appel soit inter-  
 rompu par ladite station mobile (16) en provenance  
 de ladite station de commutation (30) associée à la  
 première information de position (64), et à faire ré-  
 fférence, si la seconde information de position (64a)  
 montre que ladite station mobile (16) se situe à l'ex-  
 trémité sortante du domaine de couverture, à la ta-  
 ble (138) afin de produire une indication de celles  
 desdites stations mobiles (30) qui sont adjacentes  
 à ladite station de commutation (30) associée à la  
 première information de position (64), à effectuer  
 un accès aux stations de commutation (30) ainsi in-  
 diquées et à faire en sorte que l'appel soit interrom-  
 pu à ladite station mobile (16), par l'intermédiaire  
 de l'une des stations de commutation (30) ainsi in-  
 diquées.

Fig. 1

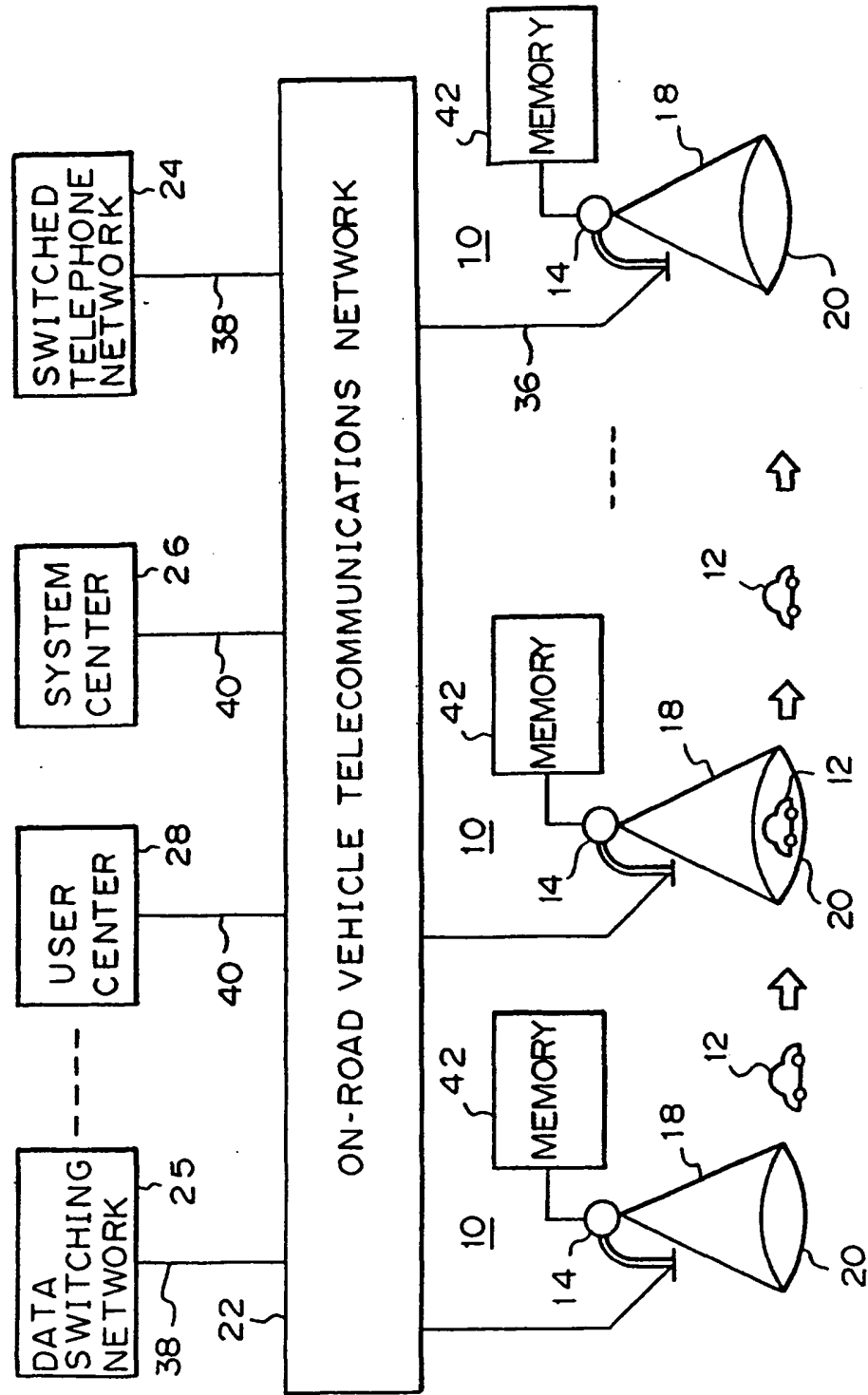


Fig. 2

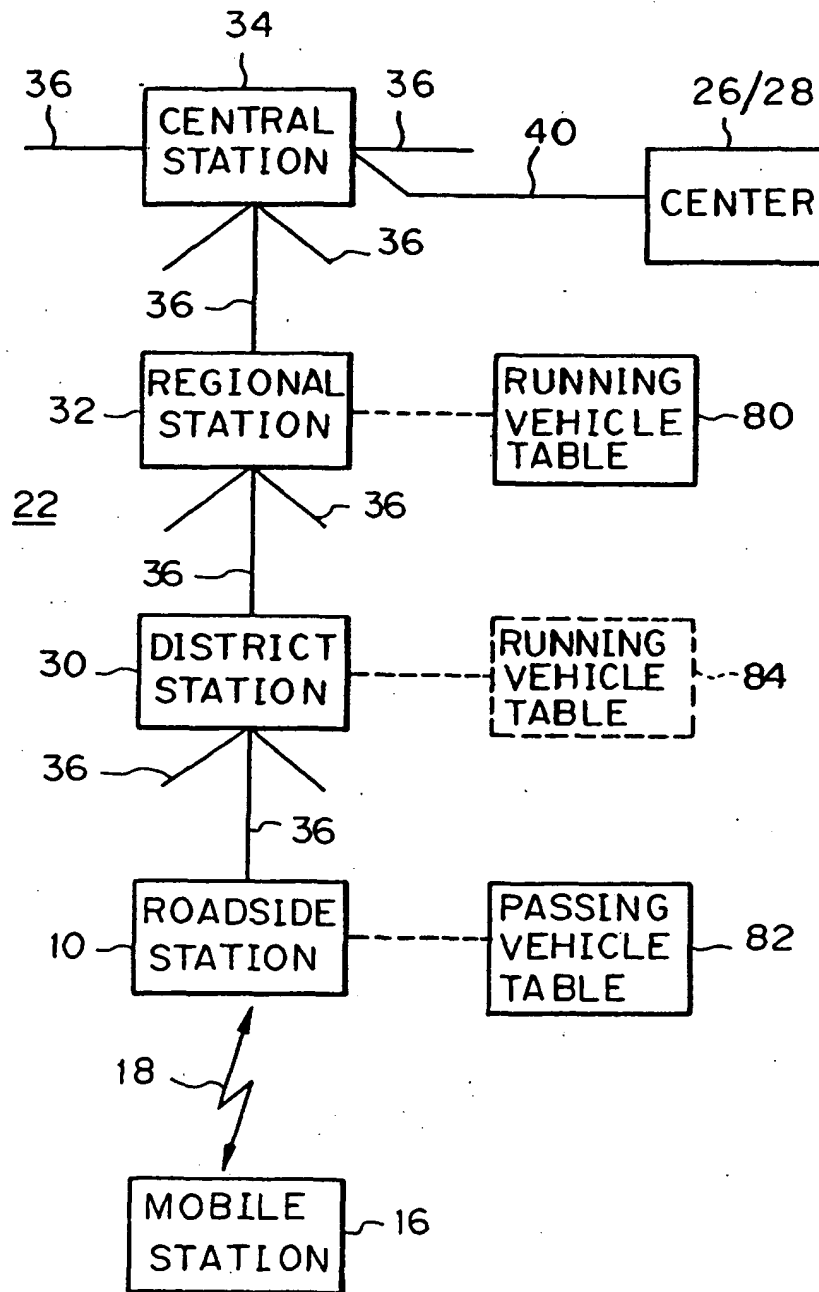


Fig. 3

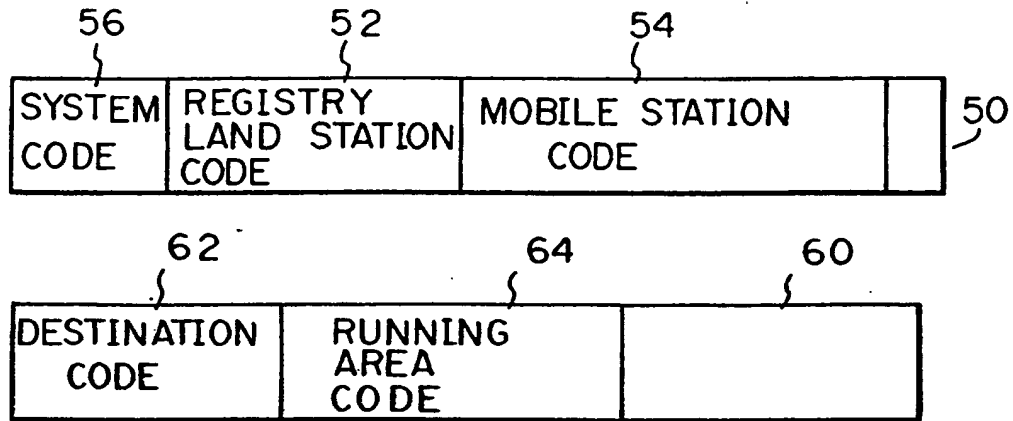


Fig. 4

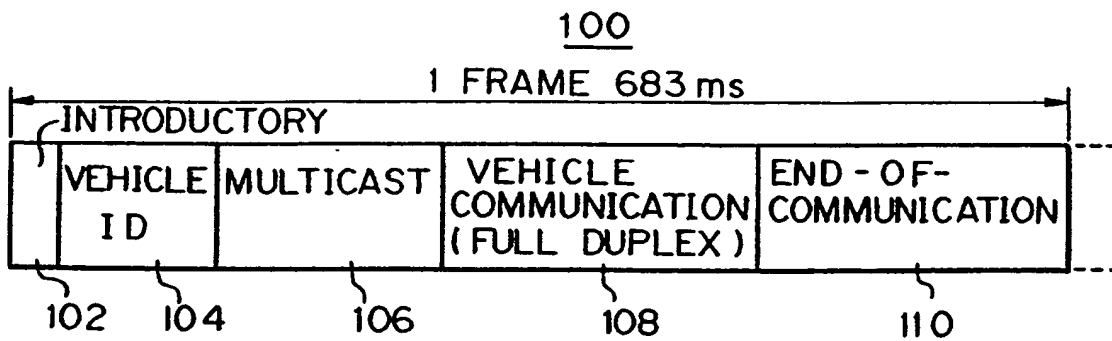


Fig. 12

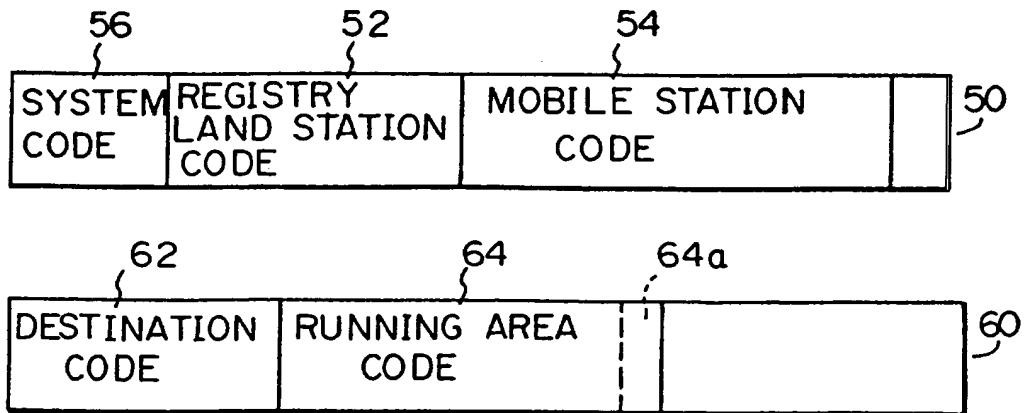


Fig. 5

MOBILE  
STATION 16

ROADSIDE  
STATION 10

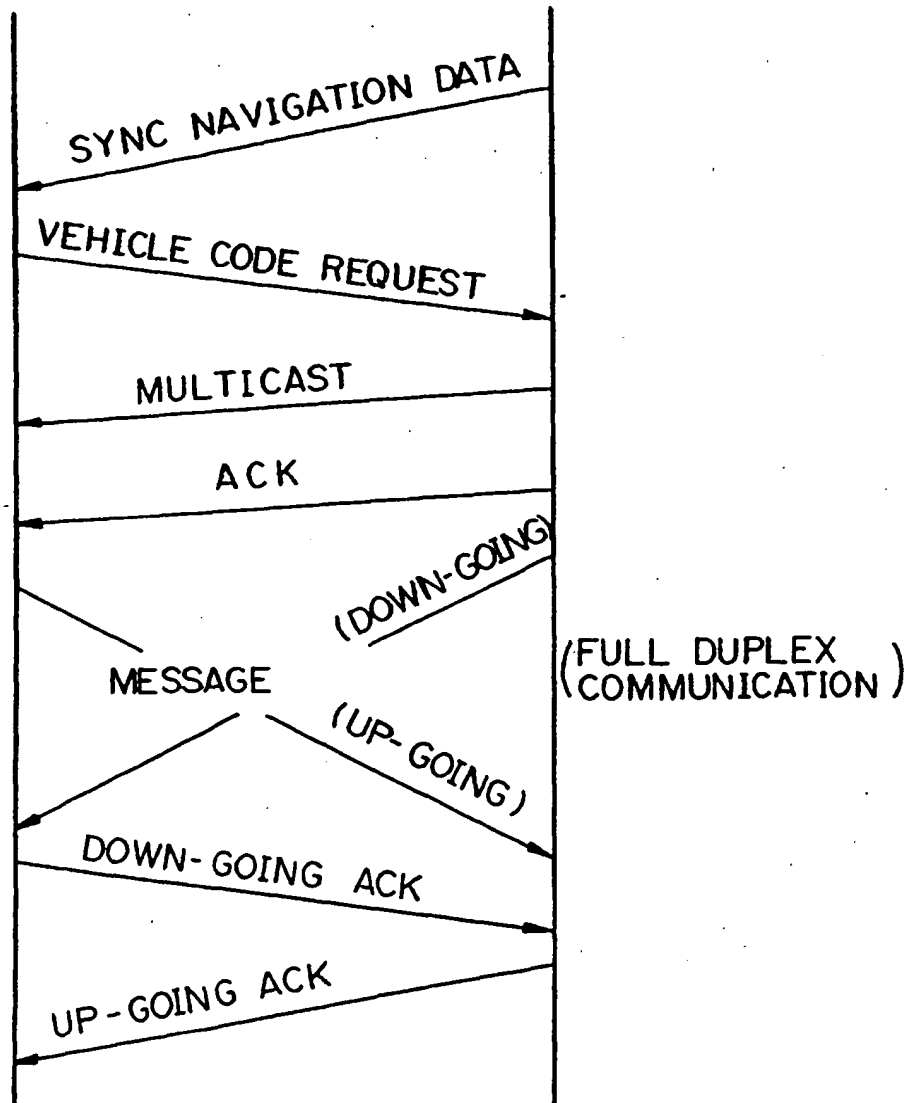


Fig. 6

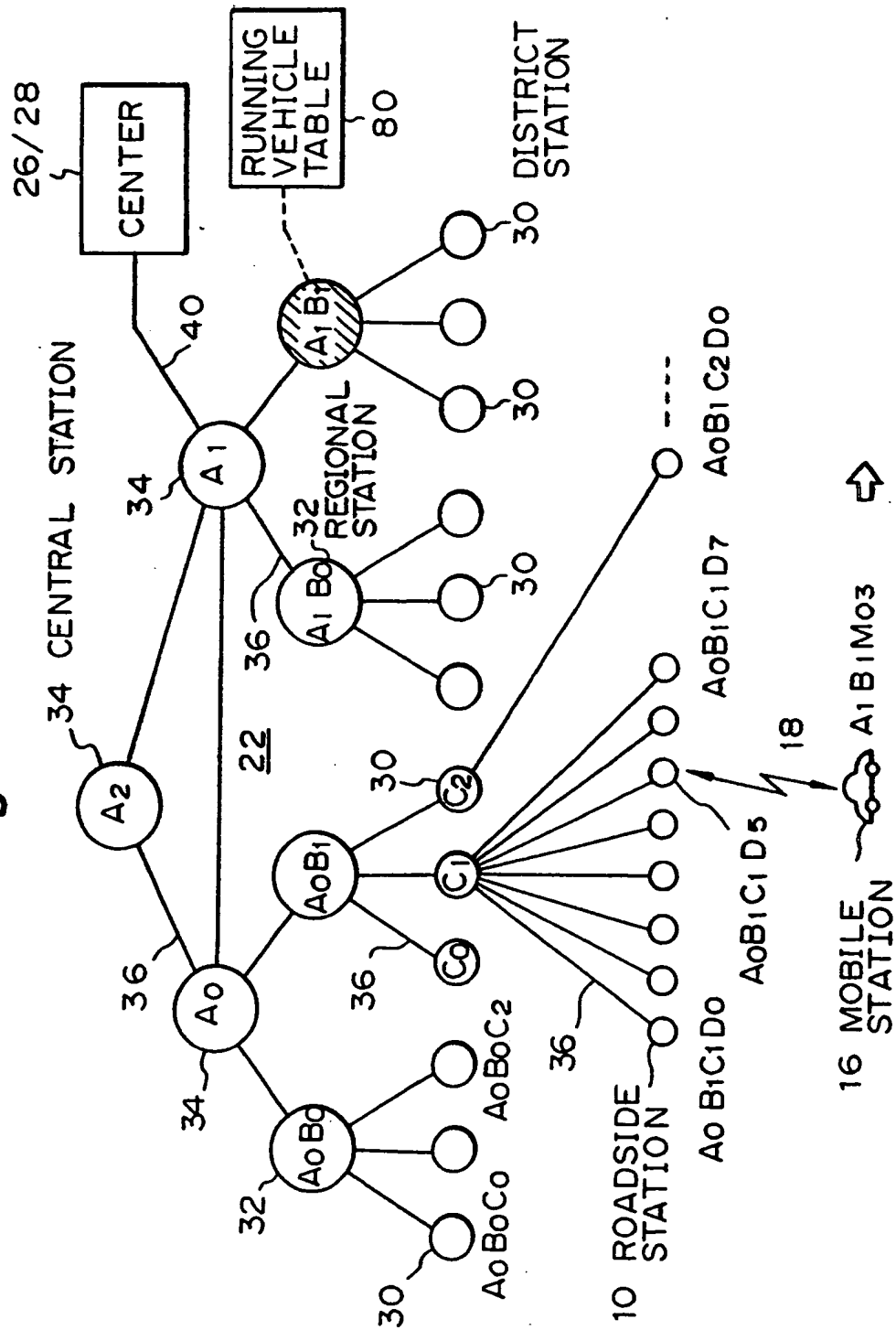


Fig. 7

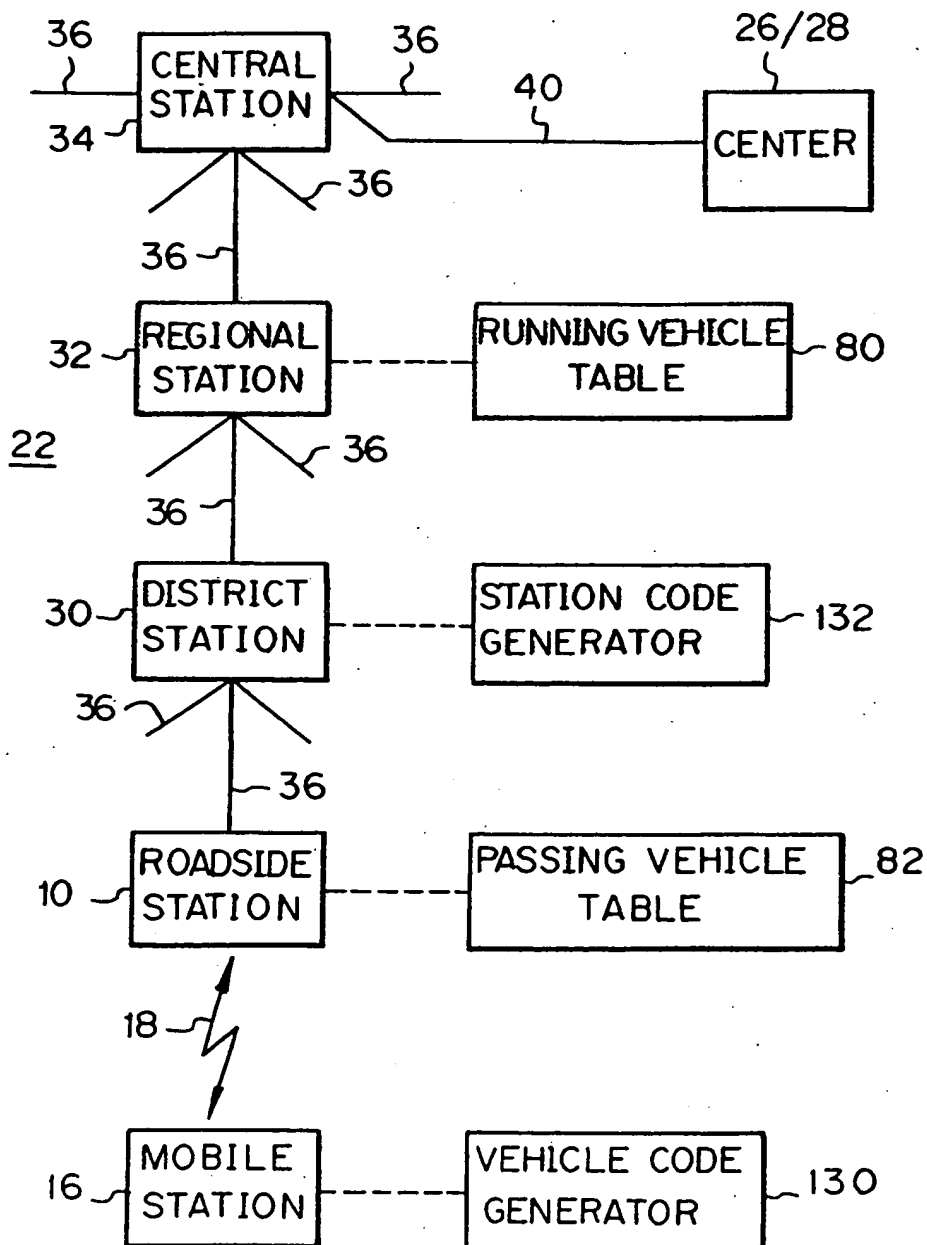


Fig. 8

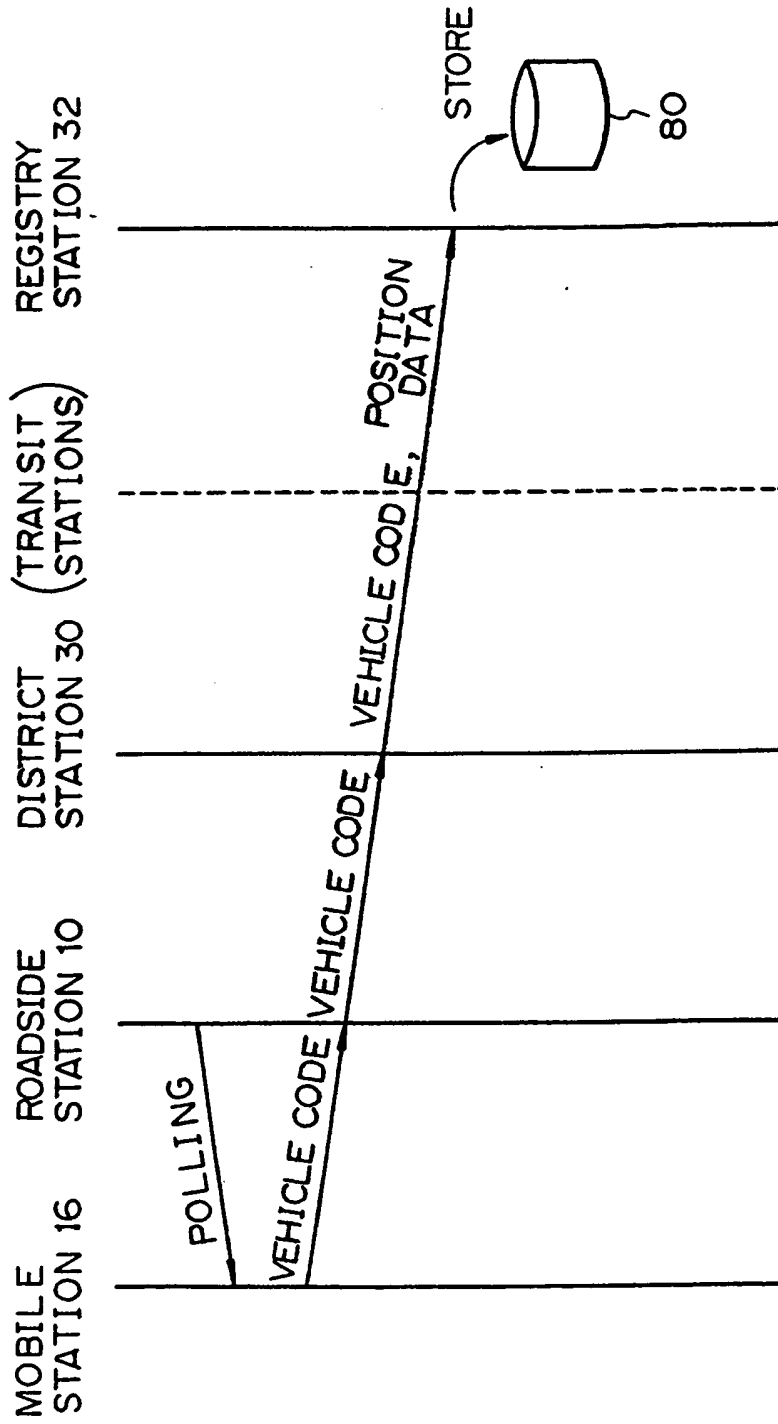


Fig. 9

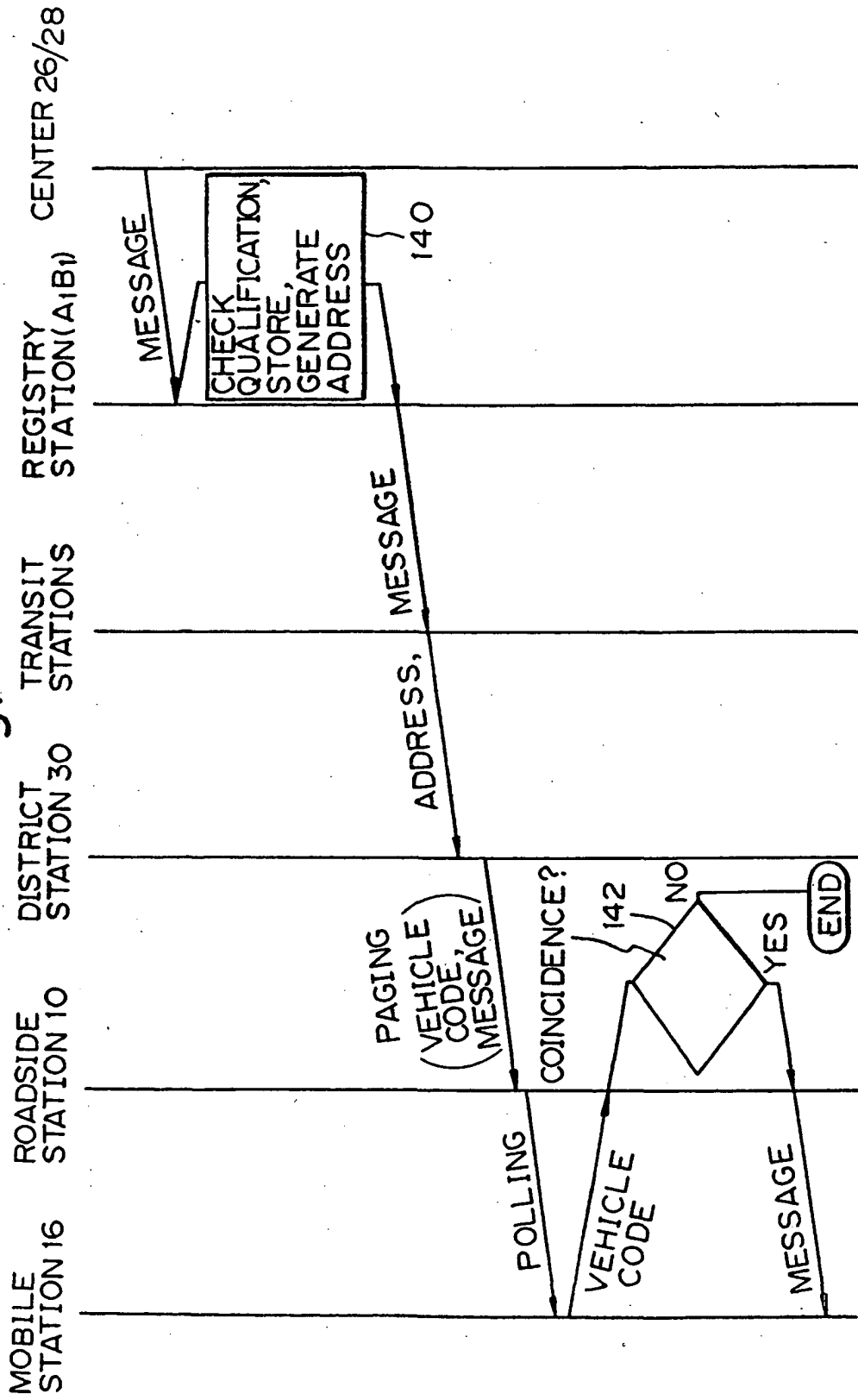


Fig. 10

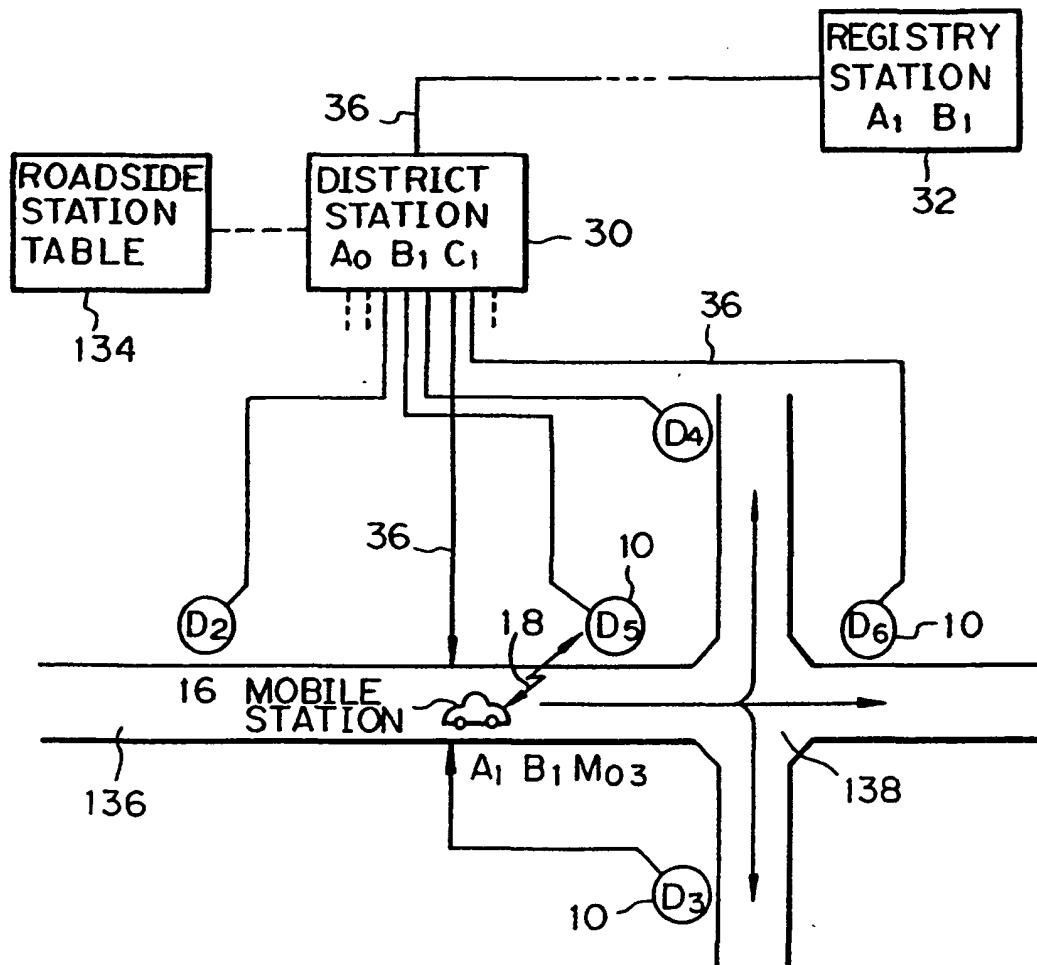


Fig. 11

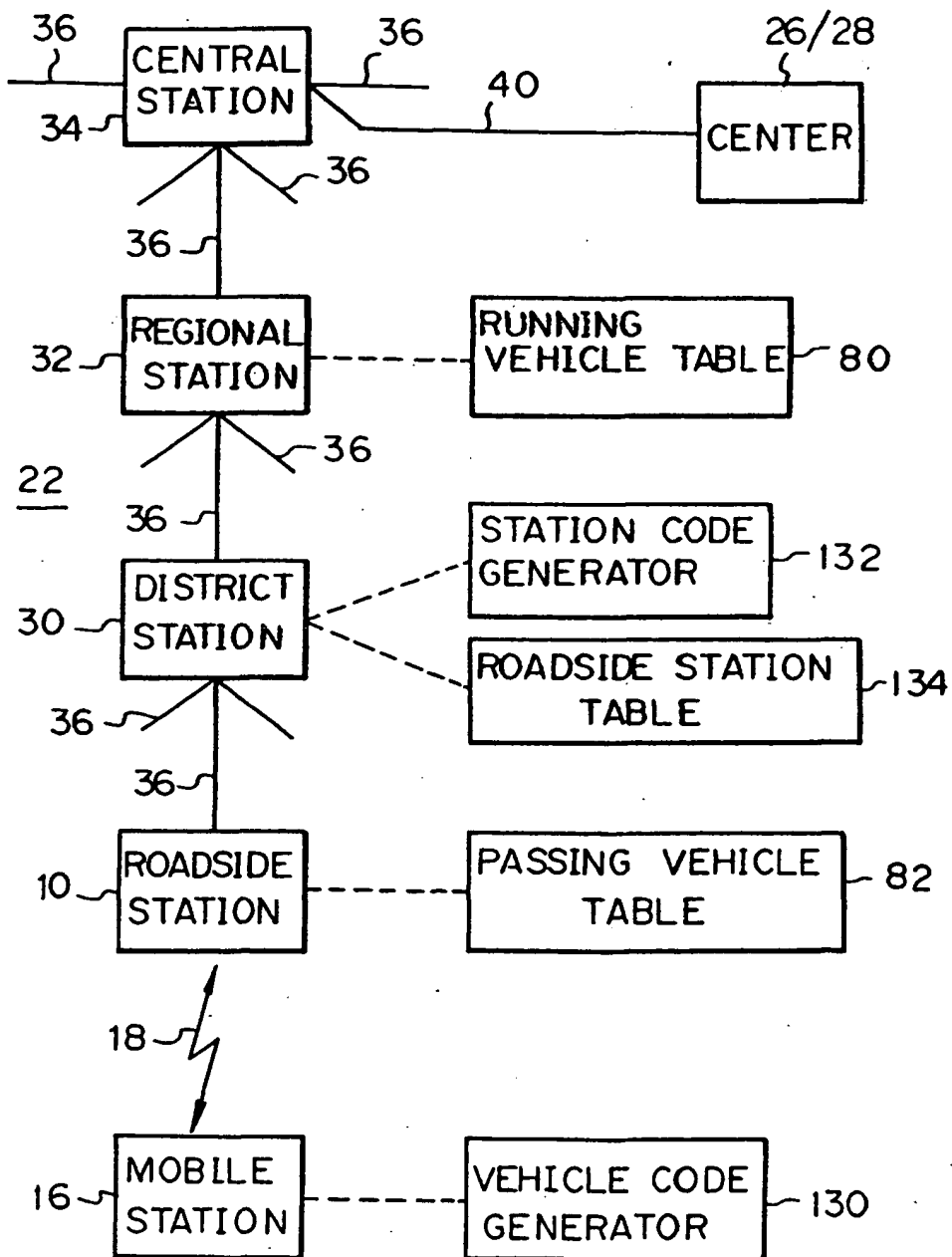


Fig. 13

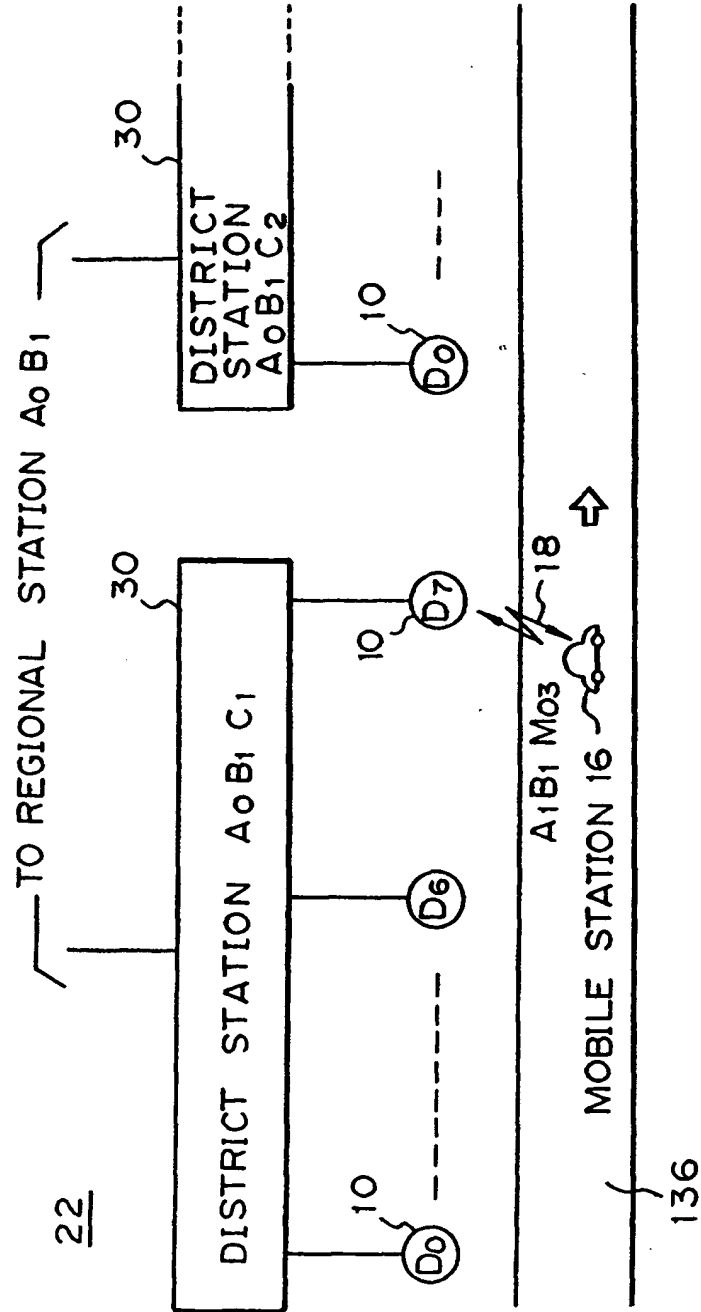


Fig. 14

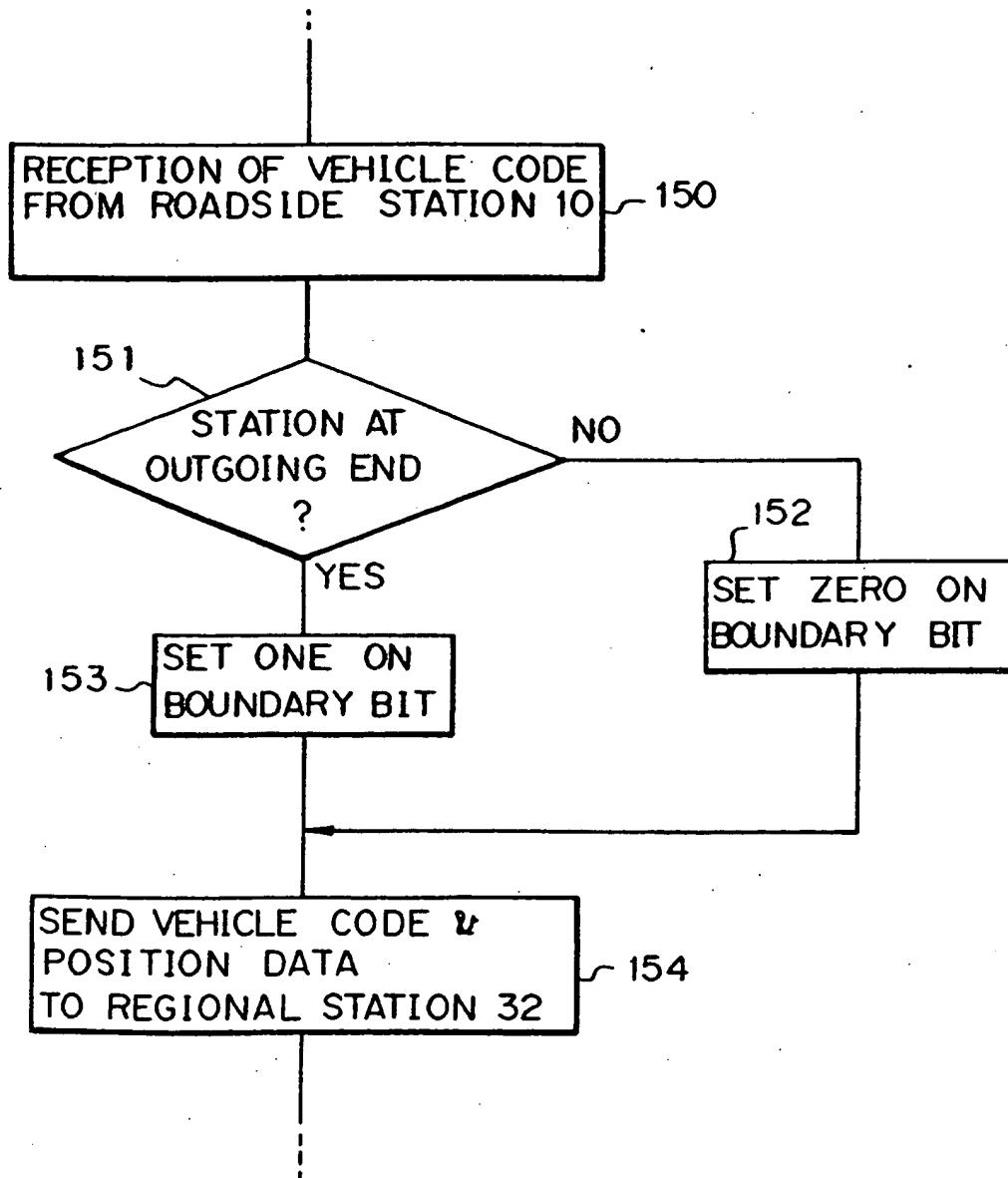


Fig. 15

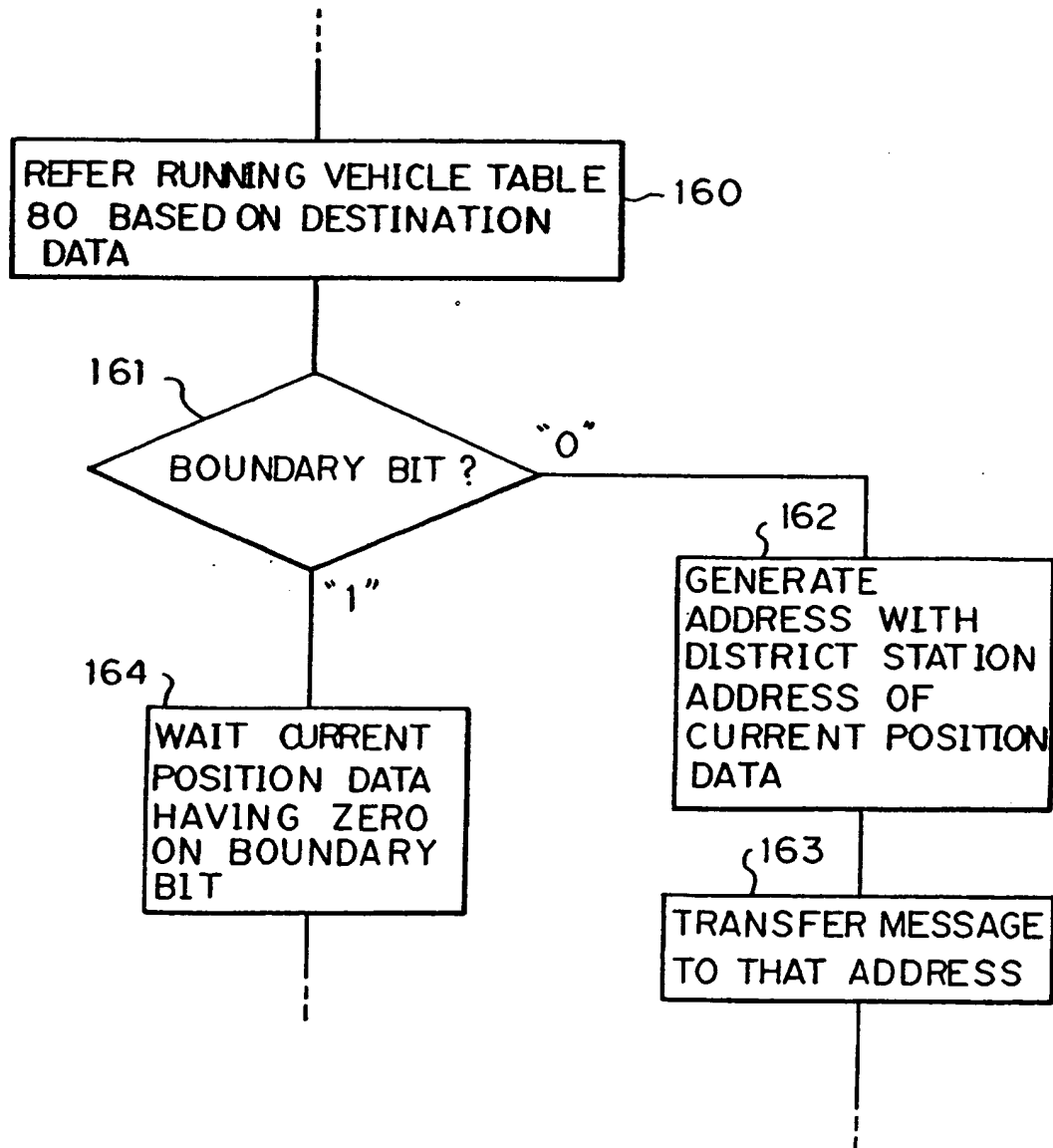


Fig. 16

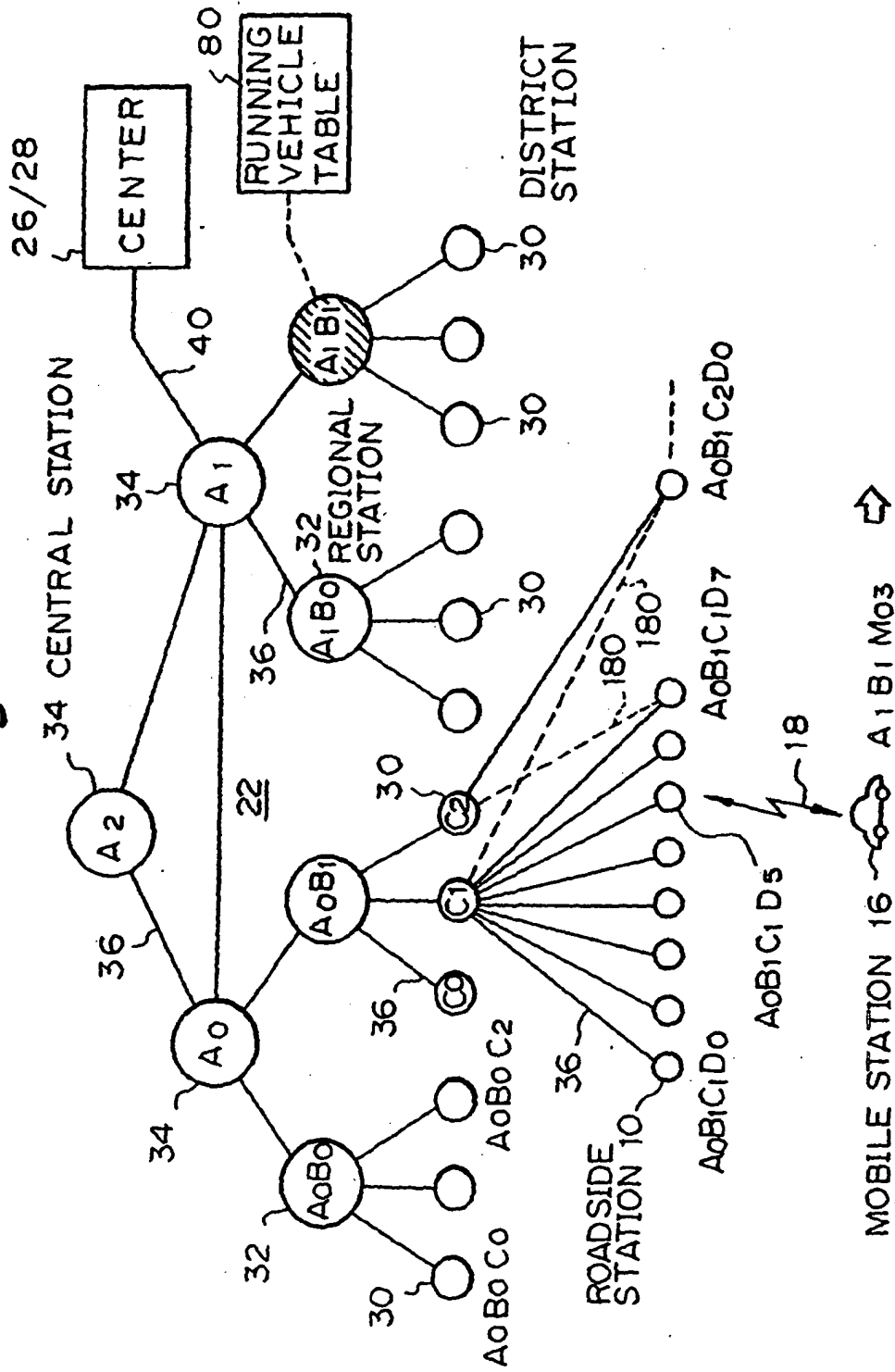


Fig. 17A

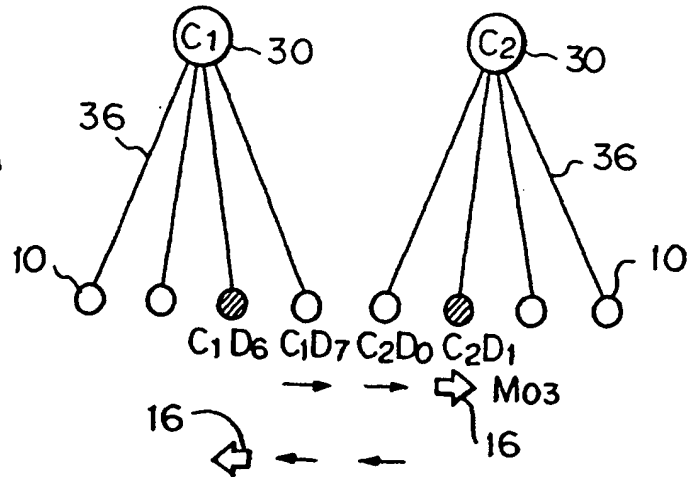


Fig. 17B

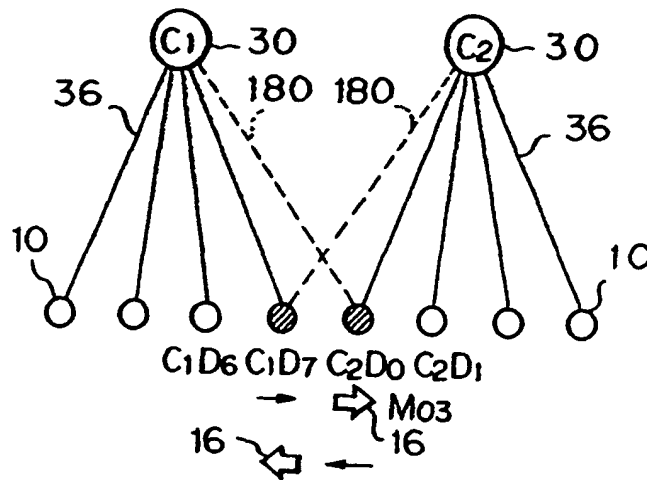


Fig. 17C

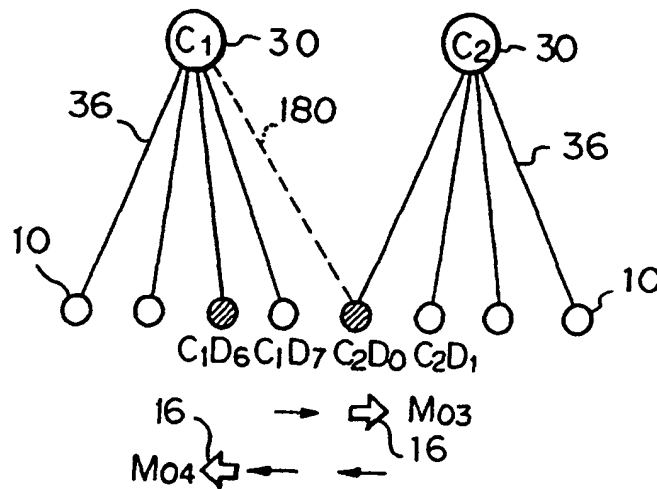


Fig. 18

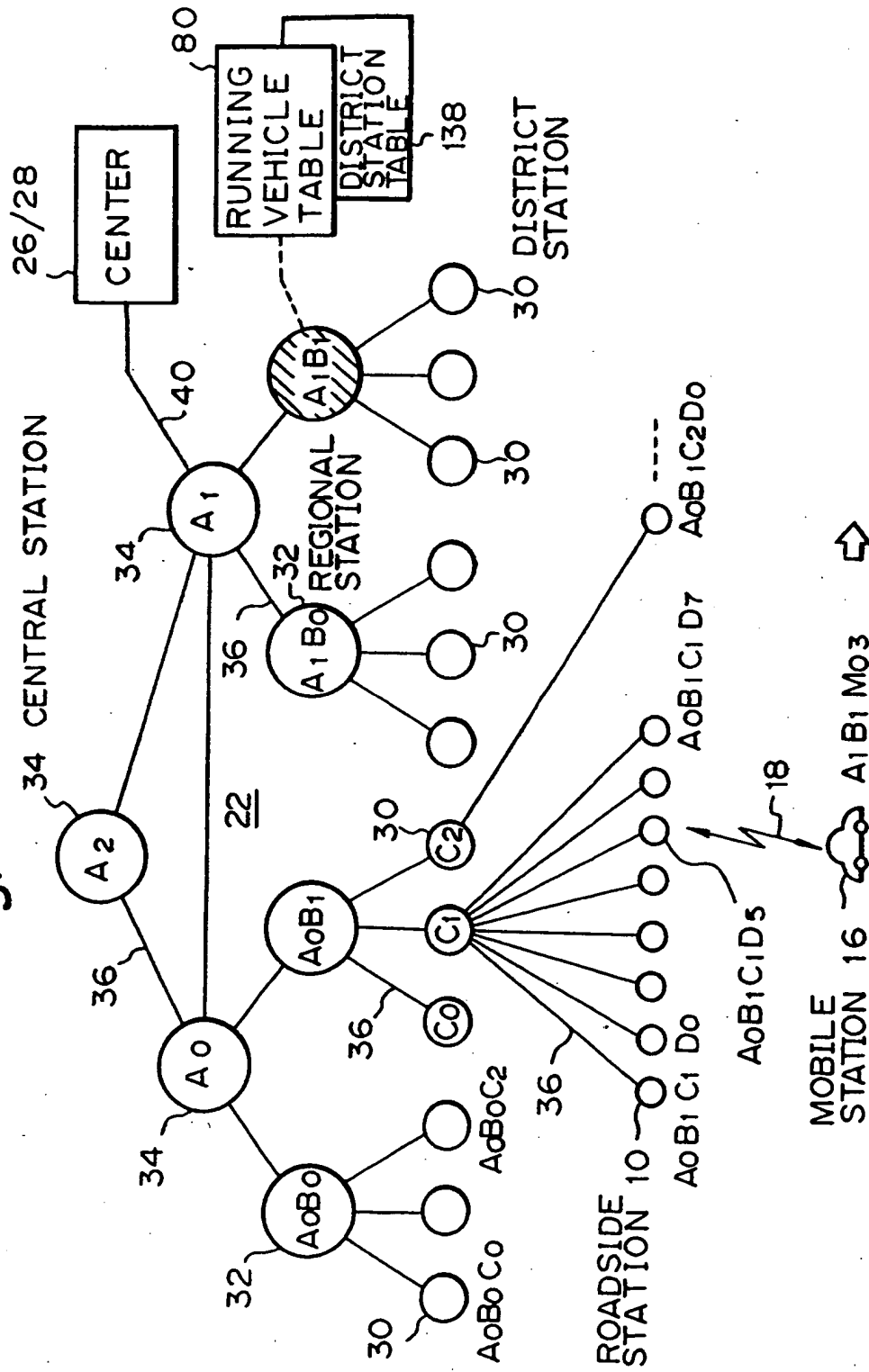


Fig. 19

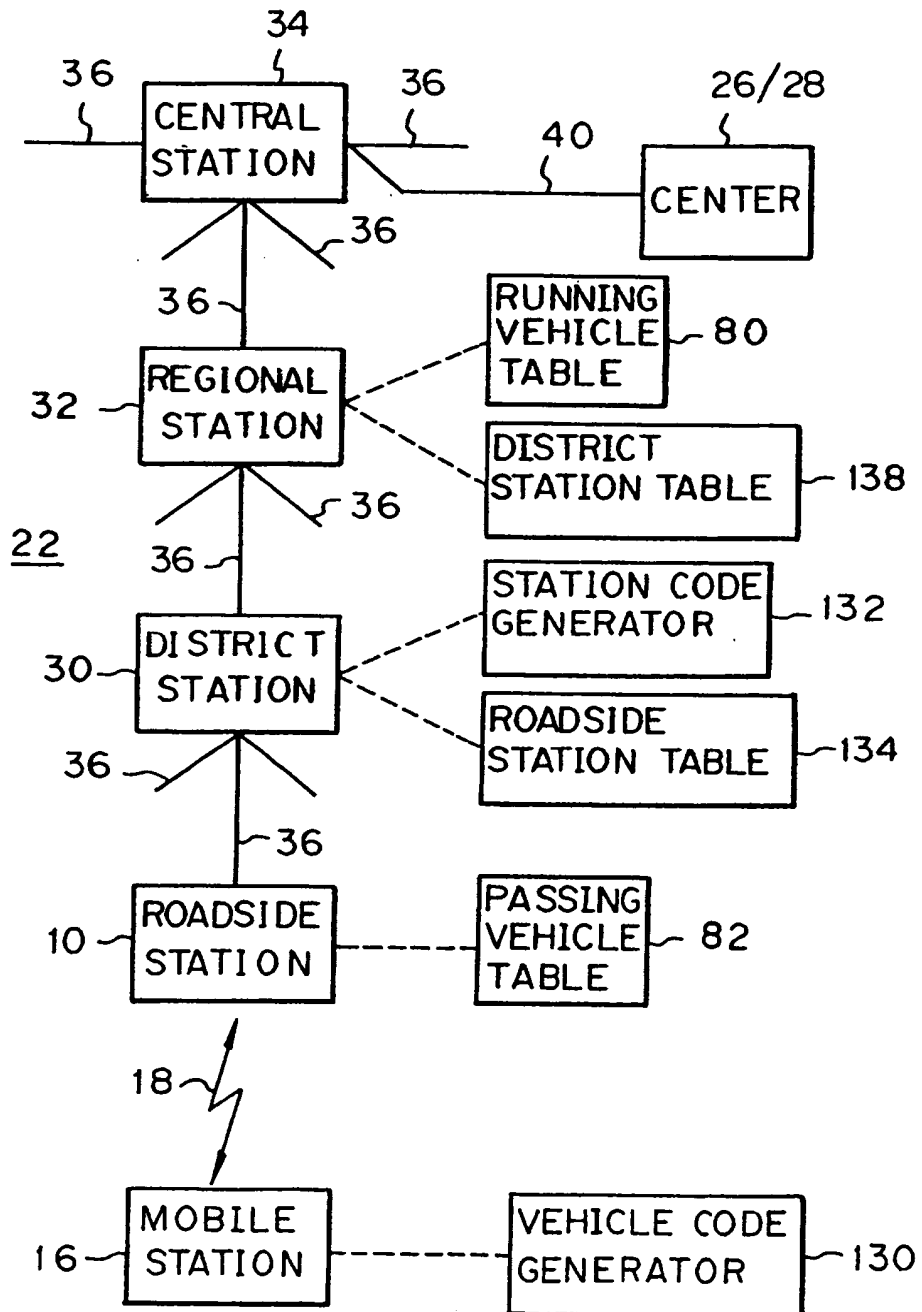


Fig. 20

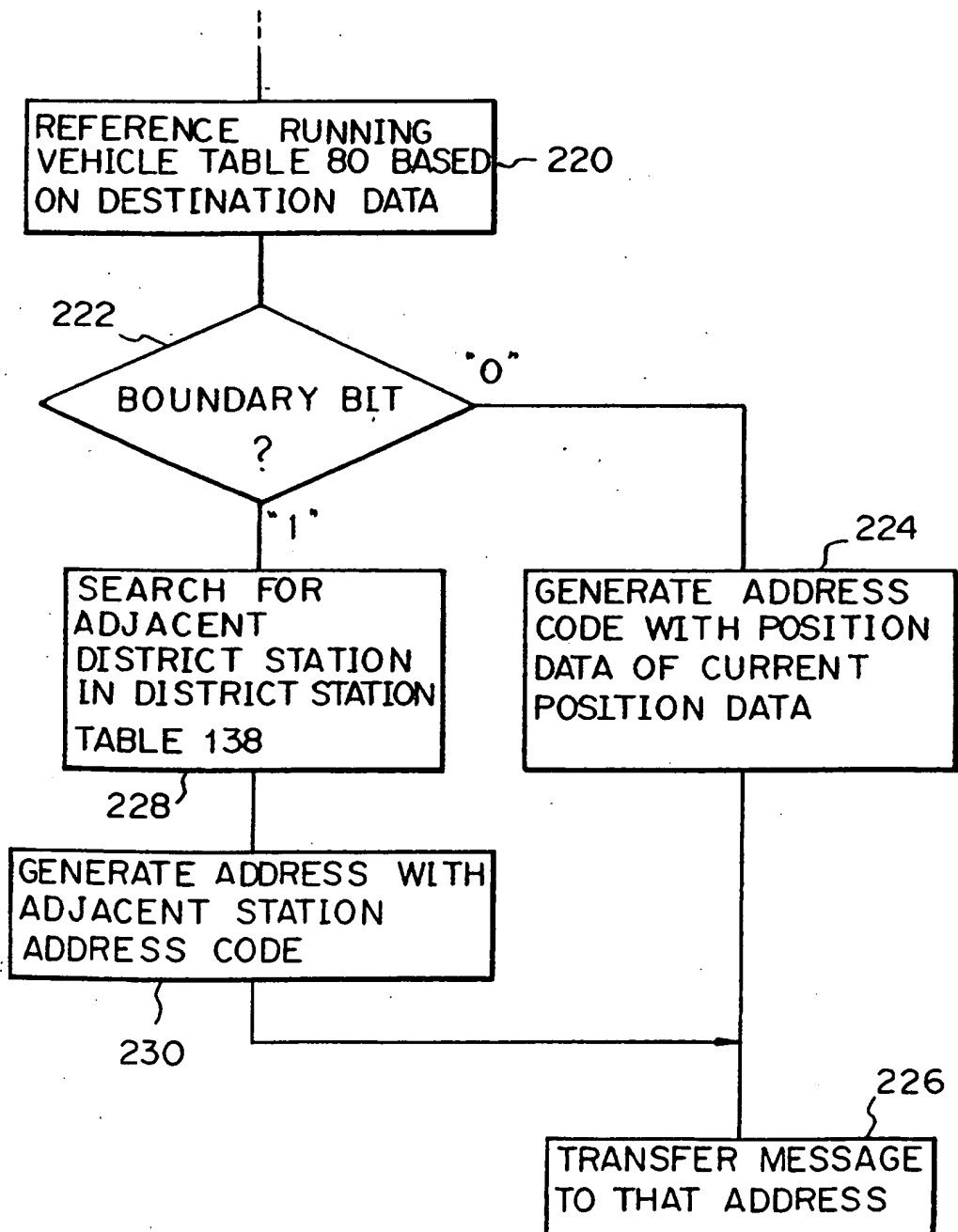


Fig. 21

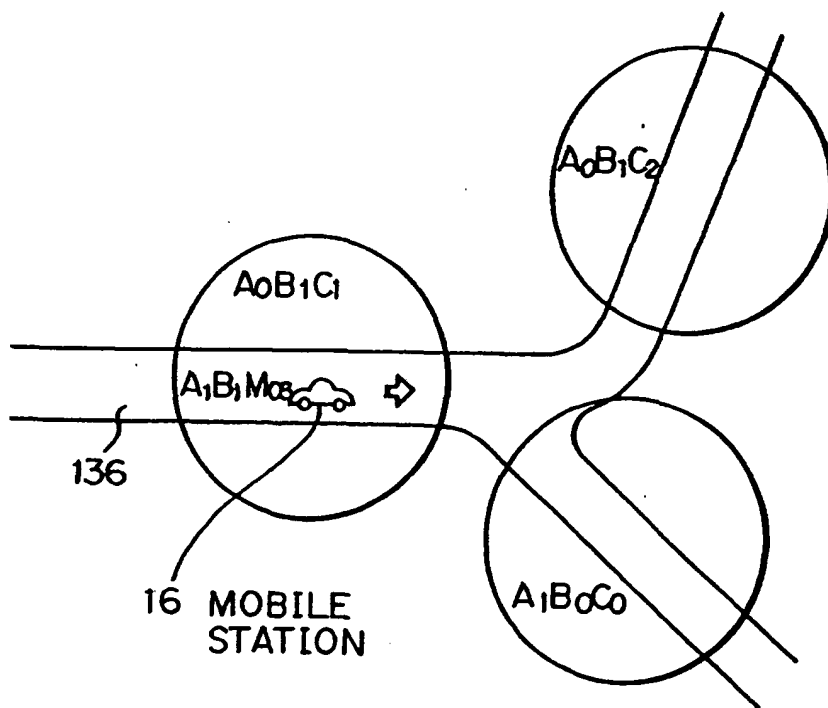


Fig. 22

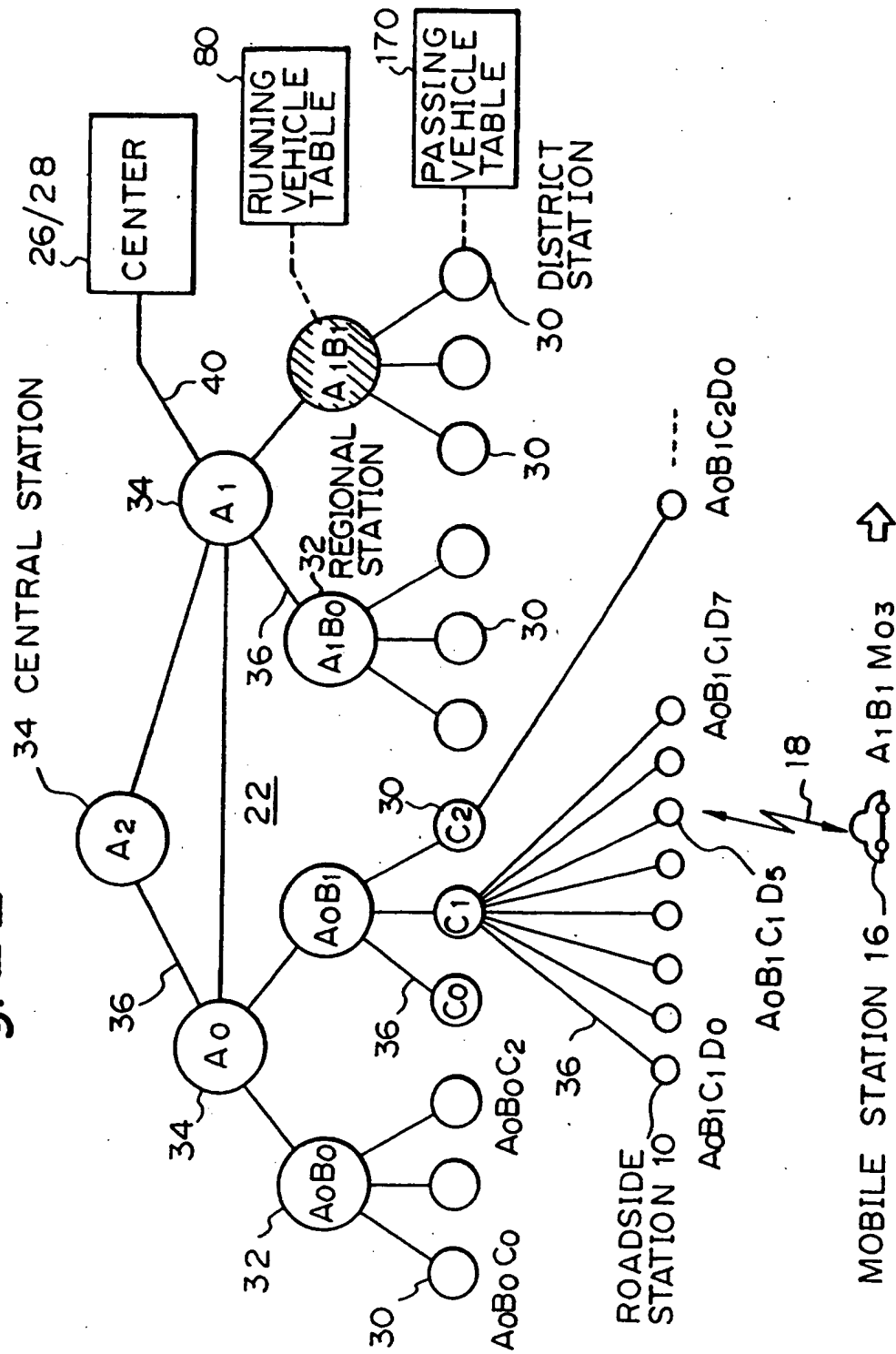


Fig. 23

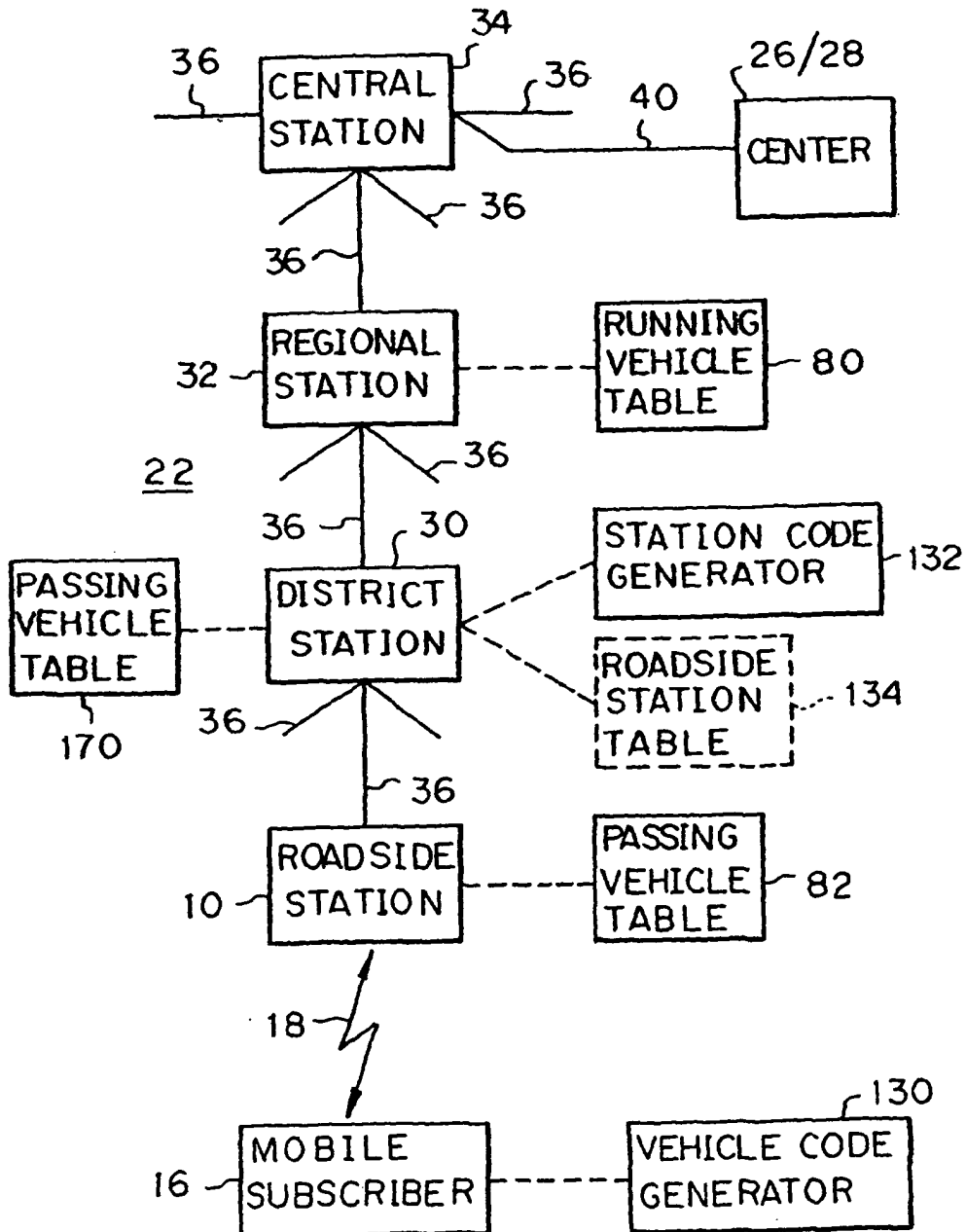
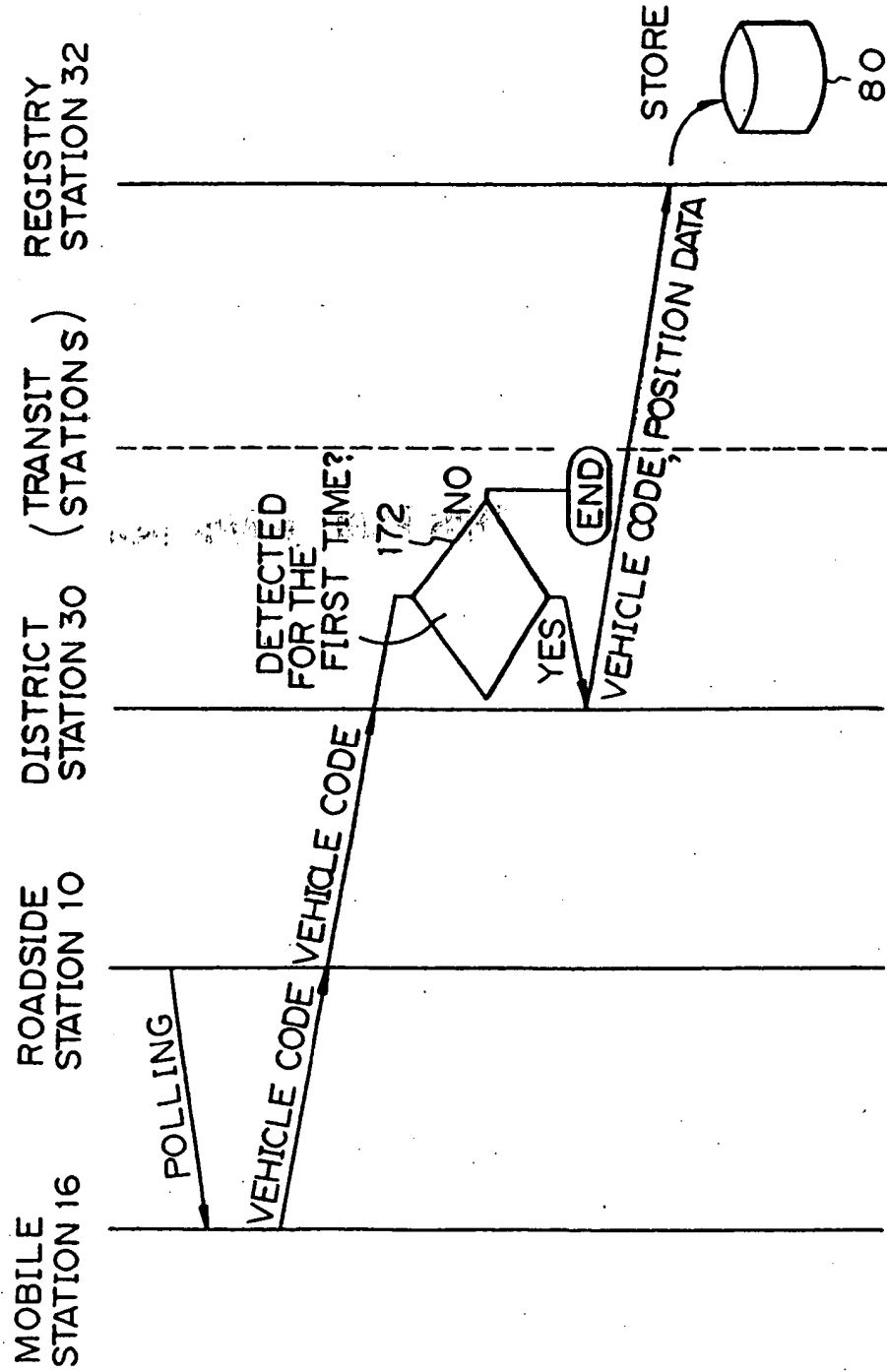


Fig. 24



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